NOISE: ITS EFFECT ON MAN AND MACHINE

THE UNIVERSITY OF MICHIGAN
SEP 20 1960
MAIN READING ROOM

HEARINGS

BEFORE THE

SPECIAL INVESTIGATING SUBCOMMITTEE

OF THE

COMMITTEE ON SCIENCE AND ASTRONAUTICS

U.S. HOUSE OF REPRESENTATIVES

EIGHTY-SIXTH CONGRESS

SECOND SESSION

AUGUST 23, 24, AND 25, 1960

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NOISE: ITS EFFECT ON MAN AND MACHINE

TUESDAY, AUGUST 23, 1960

HOUSE OF REPRESENTATIVES,
COMMITTEE ON SCIENCE AND ASTRONAUTICS,
SPECIAL INVESTIGATING SUBCOMMITTEE,
Washington, D.C.

The subcommittee met in room 214–B, New House Office Building, at 10 a.m., Hon. Overton Brooks, chairman, presiding.

The CHAIRMAN. The subcommittee will come to order.

This morning we are opening a 3-day hearing on the subject of noise. In May of this year, during the course of the open hearings on "Supersonic Air Transports," the point was clearly brought out that engine noise and the sonic boom phenomena were going to be major problems to overcome if we are to operate such airplanes over populated areas in this country. The problem could be particularly troublesome during the climbout and letdown phase of the flight profile.

I have been aware for some time of the acute situation brought about by the current noise problem surrounding the operation of today's jet airliners, guided missiles, and rockets.

I am also fully aware of the fact that progress in the air transportation field and in military weapons systems is based on larger and more powerful propulsion systems. It is my feeling that the existence of the current situation is due in large measure to a lack of an early appreciation of the true nature and the extraordinary complexity of the problem and the failure to give adequate emphasis and financial support to controlling the cause, as well as the effect.

The authority of this committee gives us jurisdiction over scientific research and development and the exploration of space. This committee will in no way trespass on previous hearings held by other committees of the Congress, but will limit its hearings to the scientific phases of this important problem.

I therefore directed that the problem receive immediate and intensive committee attention, particularly in searching for a scientific solution which could result in substantially reducing high intensity noise at its source.

To assist the committee in gathering background information for these hearings, the committee is fortunate, in my judgment, in being able to appoint Col. Roscoe Turner as a special staff consultant. He is a world-renowned aviation pioneer, a patriotic American and a man experienced in airport and air transportation management.

We also have Capt. Howard J. Silberstein, U.S. Navy, who is on loan to the committee for 1 year as a staff consultant.

We appreciate the services of both of these fine men.

We have several telegrams from Inglewood, Calif., to the committee.

If there is no objection, I will ask that some of these telegrams be placed in the record.

(The telegrams referred to are as follows:)

INGLEWOOD, CALIF., *August 20, 1960.*

OVERTON BROOKS,
Committee on Science and Astronautics, Washington, D.C.:

We urgently request Federal funds to be appropriated for jet research. Private industry is not doing the job.

Regards,

EVA VESSA.
IRENE STABE.
MARY FABIAN.
LOIS LETTO.

12 block Dixon Avenue, Inglewood, Calif.

INGLEWOOD, CALIF., *August 20, 1960.*

OVERTON BROOKS,
Committee on Science and Astronautics, House of Representatives, Washington, D.C.:

We urgently request Federal funds for jet noise suppression. Private industry not doing job. Noise unbearable in this area.

DAVID J. ANTHONY.

240 Fountainbleu, Playa Del Rey.

INGLEWOOD, CALIF., *August 21, 1960.*

OVERTON BROOKS,
Committee on Science and Astronautics, House of Representatives, Washington, D.C.:

Please allot more Federal funds for jet noise research at Los Angeles International Airport. Private industry is lagging. This is an emergency and should be treated as such. It is unbelievable this condition can be ignored by our Government as our constitutional rights are being violated night and day.

MARTIN OLSEN.

10107 Burin Avenue, Inglewood, Calif.

Mr. WOLF. Would the chairman yield for a question?

Are both of the staff consultants active now in the military service?

The CHAIRMAN. No. Colonel Turner, you mean? He is a pioneer in aviation. Everybody knows Col. Roscoe Turner. In my judgment, there is no more outstanding pioneer in aviation.

Mr. WOLF. I just want to make the record clear that he is a civilian here.

The CHAIRMAN. He is retired; yes.

Mr. WOLF. Thank you.

The CHAIRMAN. Captain Silberstein is on active duty on loan to us.

The first witness this morning is Mr. Ira Abbott, Director, Office of Advanced Research Programs, National Aeronautics and Space Administration.

Mr. Abbott, do you have a prepared statement?

Mr. ABBOTT. Yes, sir; I do.

The CHAIRMAN. I have a biography containing Mr. Abbott's background and achievement and I know the committee is fully aware of the talents of our present witness and I will therefore not take time to read his background and experience and abilities into the record.

Mr. Abbott, if you will proceed, the committee will be glad to hear you.

Mr. ABBOTT. Thank you, Mr. Chairman.

STATEMENT OF IRA H. ABBOTT,[1] DIRECTOR, OFFICE OF ADVANCED RESEARCH PROGRAMS, NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Mr. Chairman and members of the committee, I appreciate the opportunity to appear before you and acquaint you with NASA research on noise problems. The NASA and its predecessor, the NACA, have had a continuing research program on aircraft and, more recently, on missile and spacecraft noise problems.

Our first noise studies were initiated at the Langley Aeronautical Laboratory in 1930 and were directed at propeller noise. These studies provided the major contributions for the development of low-noise propellers.

After World War II, the introduction of the jet engine and the achievement of supersonic flight gave rise to a number of new noise problems which have required, and continue to require, our serious attention.

We have been concerned, on the one hand, with research on the effects of the aircraft-induced noise on the pilot, on passenger comfort, and on the general public, while on the other hand, we have had the difficult problem of providing the information required for designing aircraft structures and equipment to withstand the continuing noise battering.

More recently, the introduction of large rocket motors and hypersonic flight vehicles with their increased noise sources have further complicated our noise research problems.

The successive waves of new problems have affected the relative effort devoted by the NASA to the noise field which is, of course, only one of many problems of concern to us. We have, nevertheless, maintained a continuing and active research program on the various facets of the noise problem.

A total of 185 technical papers on various aspects of the noise problem have been published by the NACA and NASA. Our inhouse research activity has been augmented by contracted basic research at several universities: California Institute of Technology, Massachusetts Institute of Technology, and the University of Chicago.

[1] Ira H. Abbott was appointed Director of Advanced Research Programs July 1, 1959. His Office is charged with advanced research in aeronautics and space. He was named Deputy Director of the Office the previous March.

Born July 18, 1906, at Wolfeboro, N.H., Abbott was graduated from Newburyport (Mass.) High School. He received a bachelor of science degree from Massachusetts Institute of Technology in 1929.

Following his graduation, he began his 29-year career with the National Advisory Committee for Aeronautics, the predecessor of the NASA, as a junior aeronautical engineer at Langley Aeronautical Laboratory, Va. He was promoted to senior aeronautical engineer in 1941, and named Langley's Assistant Chief of the Full-Scale Research Division in 1944. The following year he became Assistant Chief of the Research Department.

Abbott was transferred to NACA headquarters, in Washington, in 1948, as aeronautical consultant and was named Assistant Director of Research (Aerodynamics) in 1950. When the NASA was established Oct. 1, 1958, he was appointed Assistant Director of Research for Aerodynamics and Flight Mechanics.

He is a member of the Civilian-Military Liaison Committee, and a fellow of the Institute of the Aeronautical Sciences. From 1957 to 1958 Abbott was Chairman of the Wind Tunnel Panel of NATO's Advisory Group on Aeronautical Research and Development.

Mr. and Mrs. Abbott (the former Martha Leola Streeter) have three children and live at 3704 Bradley Lane, Chevy Chase, Md.

DEFINITION OF NOISE LEVEL—DECIBEL

Before discussing NASA's research activity, it will be helpful to pause briefly and define the term "decibel," which is a unit generally used by physicists and acousticians to describe the relative intensity of a noise.

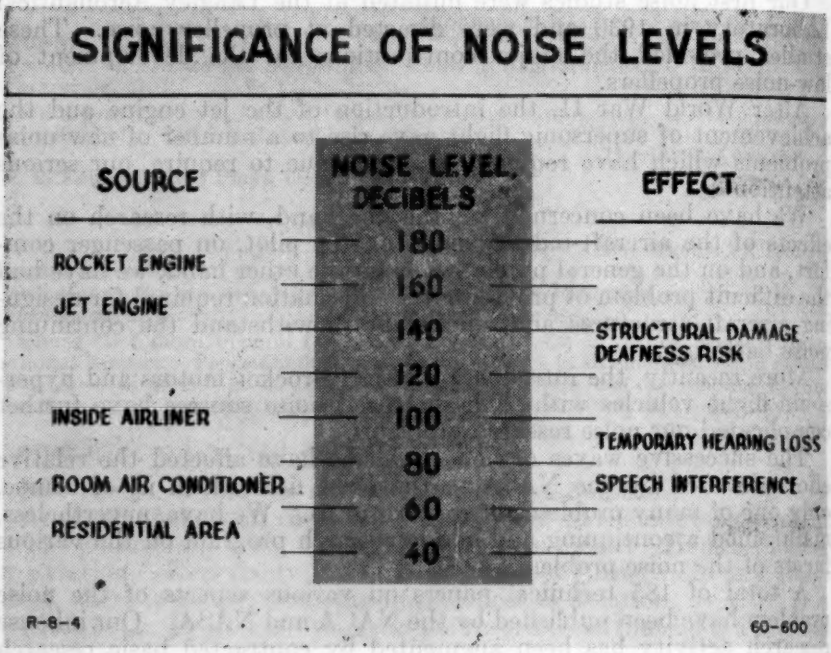
Figure 1 shows where various noise sources fall on the decibel scale and some of the effects that various noise levels produce.

The CHAIRMAN. May I interrupt here.

All members of the committee have a copy of this diagram. I think you are alluding to that; aren't you?

Mr. ABBOTT. I am alluding more specifically to the chart up here.

FIGURE 1



As indicated on the chart, the background noise level in a residential area is at about 50 decibels, while the noise produced by a room air conditioner is about 70 decibels.

The CHAIRMAN. What is a decibel?

Mr. ABBOTT. A decibel is a unit of the noise source, and I am trying to explain the term "decibel" by these descriptions of the level of various noise sources and some of their effects, because the technical description is rather complex. It actually is a logarithmic scale.

The CHAIRMAN. It is an arbitrary unit?

Mr. ABBOTT. Arbitrary unit of the noise level.

The CHAIRMAN. Indicating the intensity of the noise.

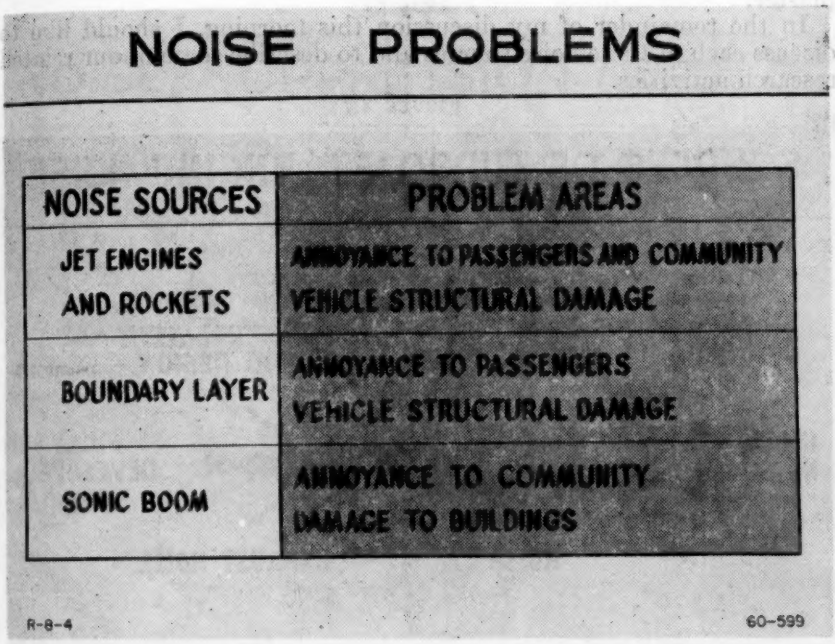
Mr. ABBOTT. Yes, sir.

Passenger compartments of modern airliners vary from about 90 to 100 decibels, while the noise levels close to some of our larger jet and rocket engines may get up to 150 to 170 decibels, respectively.

Let us consider the effects of various noise levels. At 70 decibels, we begin to get interferences with normal conversation, while sustained exposure to noise levels of around 90 decibels normally yields some temporary reduction in hearing acuity. Above about 130 decibels we begin to get definite risk of human deafness while at about 140 decibels, structural damage to airplanes ensues.

One of the facts which should be remembered about decibels is that each increase of 6 decibels corresponds to a doubling of the noise pressure level and thus the scale from 40 to 180 decibels covers a tremendous range of noise variation—roughly a 10-million-fold increase.

FIGURE 2



NOISE SOURCES AND PROBLEMS

Figure 2 outlines the major noise sources and some of the problems introduced by them. We see that there are three principal sources of noise in aeronautics and astronautics. The first is the engine itself, either the jet engine or the rocket. In both cases the highspeed, hot-air flow from the engine exhaust is the major noise source. The intense jet-engine noise is a nuisance to airplane passengers and to the airport community and has been responsible for a wide variety of structural damage to aircraft vehicles. The even more intense noise of the larger rockets is of concern to us in regard to damage to structures and guidance equipment.

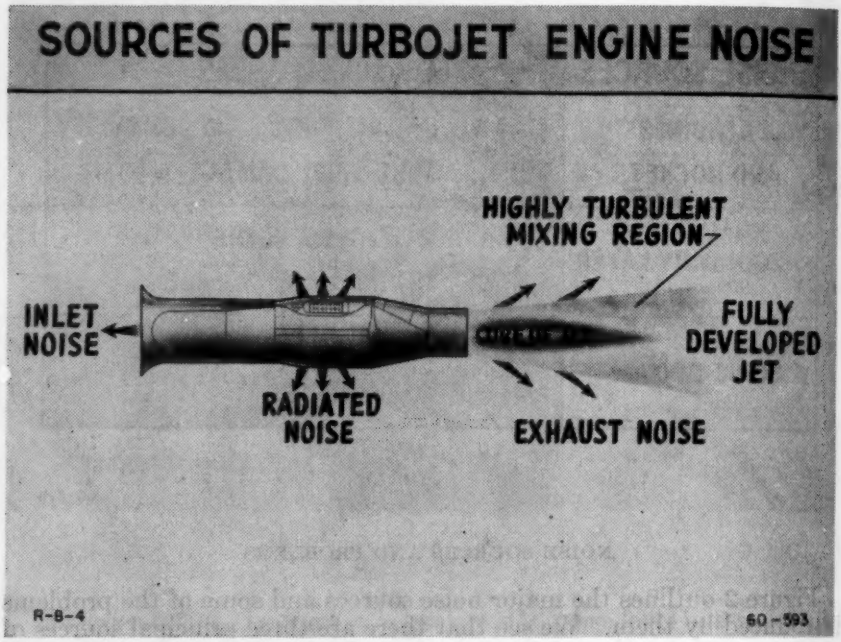
Such problems are especially serious for man-carrying vehicles such as Mercury. Our large rocket firings have been made from relatively isolated Department of Defense ranges and have so far not created a major community problem.

The second major noise source is the boundary-layer noise caused by the turbulence created as the air rushes over the vehicle. This kind of noise is mainly of concern with respect to passenger comfort and in regard to vehicle structural damage. It is the primary noise source heard during cruise by passengers in current jet transports and is expected to become more serious as airspeeds increase further.

The third noise source is the sonic boom which is associated with the airplane pressure and shock field and is heard on the ground as a loud explosive boom when an airplane flies by at supersonic speeds. This type of noise is of particular significance in regard to the supersonic transport. It is not only a nuisance to people on the ground but may cause minor damage to buildings such as broken glass and cracked plaster.

In the remainder of my discussion this morning, I should like to discuss each of these noise sources and to describe some of our related research activities.

FIGURE 3



JET-ENGINE NOISE

Figure 3 illustrates some of the principal noise sources of a jet engine. As we can see from this chart, noise arises from the inlet and compressor region of the engine, the combustion chambers, and the exhaust nozzle.

Of the three, the exhaust noise is the most serious although the inlet noise is of growing concern for the approach and landing conditions of high-speed airplanes. The noise radiating from the combustion chamber is normally negligible.

In recent years, the application of proven military jet engines to commercial transports has exposed many metropolitan areas to their

noisy character with resulting demands for the development of effective noise reducers.

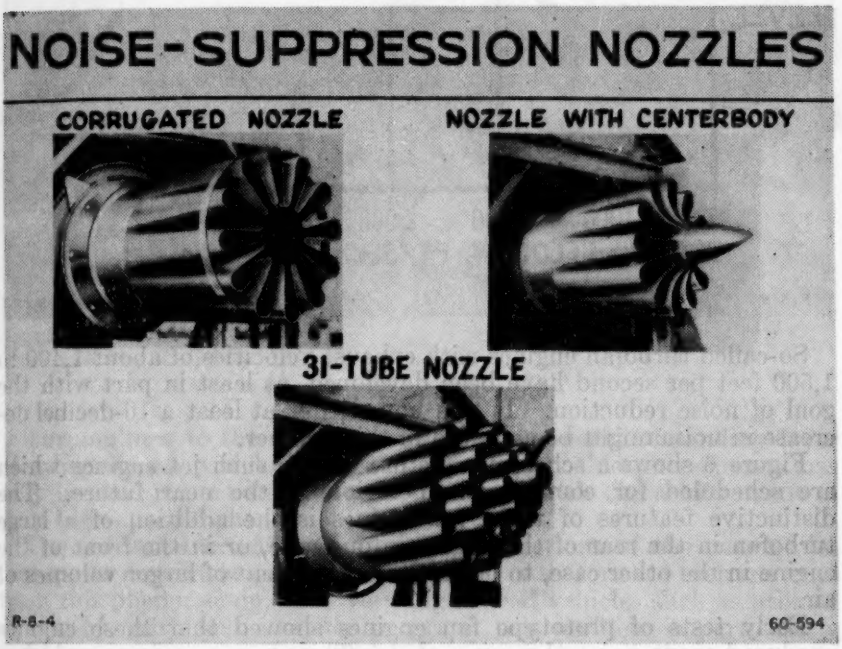
The NASA and the aircraft industry in this country, and the British aircraft industry have had a relatively large cooperative research and development program underway to satisfy this demand.

Figure 4 shows some of the noise-suppression nozzle configurations that have been actively studied and tested at our Lewis Research Center. I also have a model of another approach which uses a retractable shroud. This is the shroud which is retractable.

The CHAIRMAN. What is the shroud, the upper part?

Mr. ABBOTT. This gray part is the shroud and that is retractable back over this [indicating].

FIGURE 4



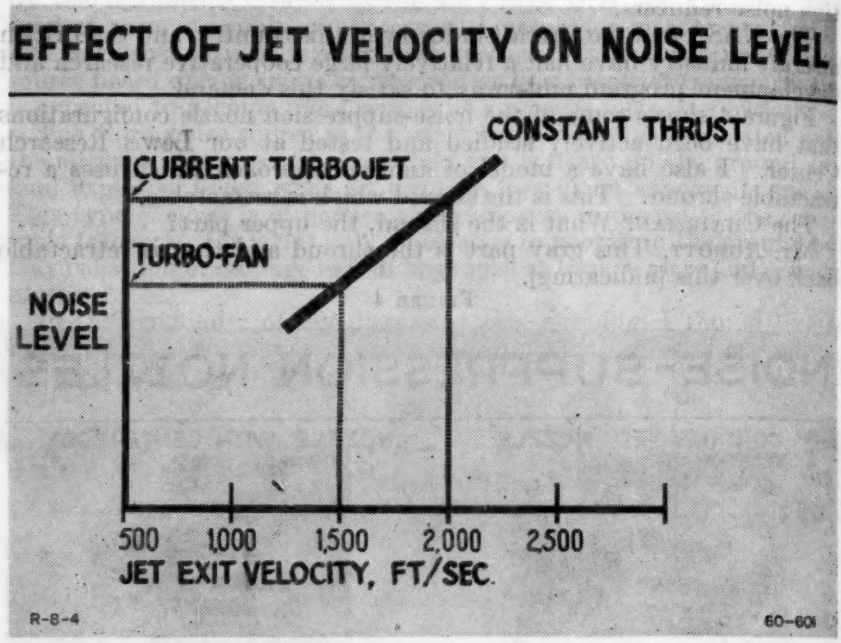
These nozzles have been moderately effective, reducing the noise level by 3 to 6 decibels. Although this reduction is not entirely satisfactory, devices of this general type have been intensely developed by industry and have found wide application as an interim fix.

The indifferent success of the noise-suppression nozzles has turned the attention of both the NASA and the industry to a more basic approach to jet-engine noise reduction.

Figure 5 (p. 8), indicates the basic physical principle utilized in this approach. The chart shows that for a constant thrust level the noise increases directly with the jet-exit velocity.

Current jet engines have a jet-exit velocity of about 2,000 feet per second and have a relatively high-noise level. As can be seen from the chart, if the jet-exit velocity can be reduced, the decibel or noise level would likewise be reduced. However, in order to achieve this noise reduction without a substantial loss in thrust, it is necessary to move a greater volume of air at this lower velocity.

FIGURE 5



So-called turbofan engines with exhaust velocities of about 1,400 to 1,500 feet per second have been developed, at least in part with the goal of noise reduction. It was hoped that at least a 10-decibel decrease in noise might be achieved in this manner.

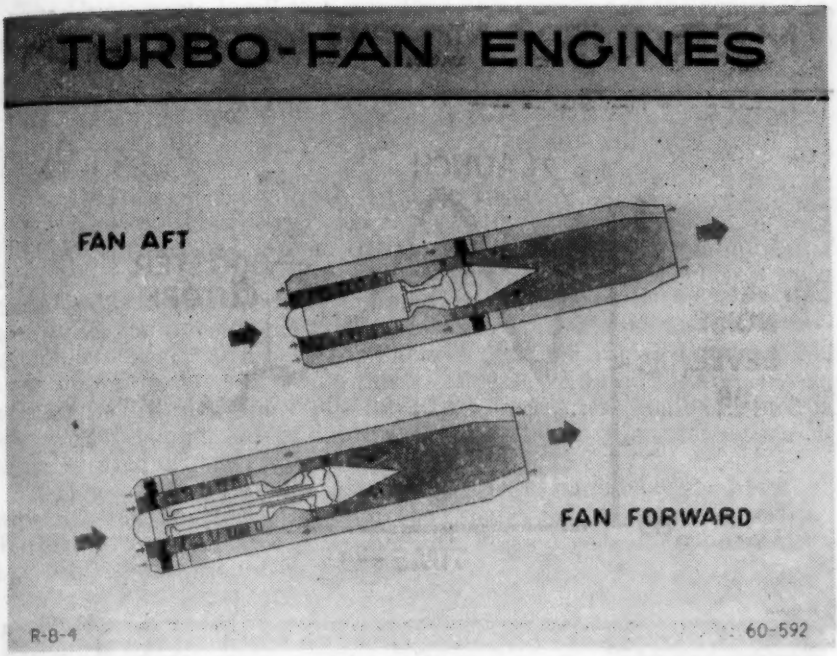
Figure 6 shows a schematic picture of two such jet engines which are scheduled for commercial operation in the near future. The distinctive features of these jet engines is the addition of a large turbofan in the rear of the engine in one case, or in the front of the engine in the other case, to permit the movement of larger volumes of air.

Early tests of prototype fan engines showed that these engines produced more noise than expected. This disappointing result has been traced to mixing problems in the exhaust flows and to the presence of siren-pitch-type noise emanating from the fan blades.

Although the engine manufacturers have been able to achieve significant reductions in the noise of these engines, the noise levels are still higher than desired. For this reason the NASA has undertaken a basic research program concerning problems of noise generation specific to fan engines.

A systematic study is being made of the relation between factors affecting fan design such as blade shape, blade spacing, blade and air speeds, and distance between rows of blades and the noise produced by the fan. It is expected that such research will allow further noise reductions on the forthcoming fan engines and that it will provide necessary design information for future engines for supersonic transports.

FIGURE 6



BOUNDARY LAYER NOISE

Turning now to the second major noise source, the boundary layer of a high-speed vehicle, I might first say that this phenomenon has only become important in recent years and with the achievement of very high-speed flight.

The increased noise levels in the rear sections of the current jet transports as contrasted with those in the more forward sections arise from this phenomenon. On very high speed vehicles such as utilized in our Mercury man-in-space program, this problem is particularly vital in regard to the protection of instruments and the passengers.

In studying boundary-layer noise we have obtained measurements of boundary-layer noise from a number of airplanes and some of the earlier Mercury capsule test shots.

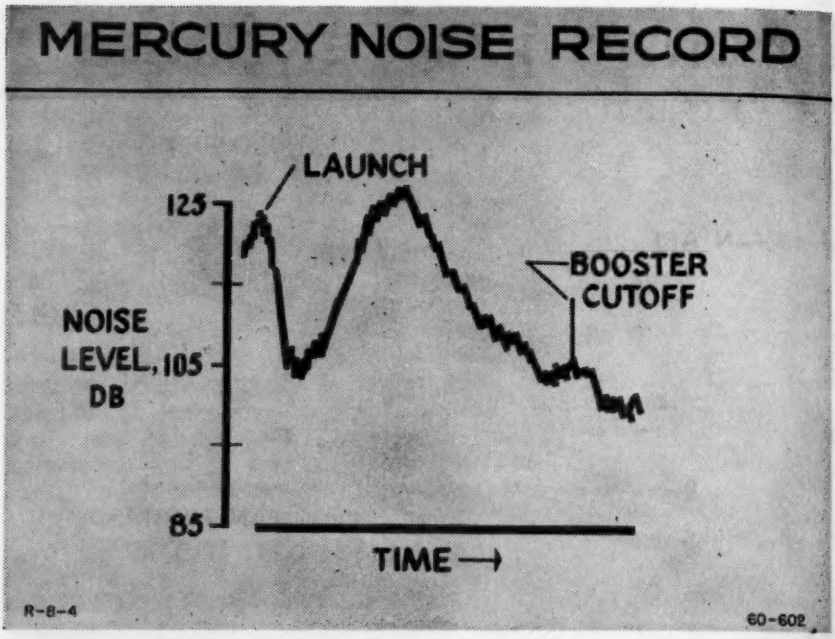
I would like to play a recording for you of measurements obtained in the inside of an early model of the Mercury space capsule during a test shot using an Atlas booster.

As indicated in figure 7 (p. 10), you will first hear the loud noise of engine ignition and lift-off which reached almost 125 decibels.

The CHAIRMAN. Are you going to have any cotton for the ears of these Congressmen in this noise demonstration?

Mr. ABBOTT. We can cut down the intensity if you wish. We planned to play it at about 115 decibels, which will represent about what the—approximately what the astronaut will hear through his protective flight helmet. The speakers are located in the two corners of the room at your right and left.

FIGURE 7



Representative BECKER. Mr. Chairman, I suggest they go on full blast, so you understand what we have to put up with at Idlewild Airport on Long Island.

The CHAIRMAN. If it does get high, we can stop it.

Mr. ABBOTT. All right. We will stop it at any time you indicate. The noise level you will actually hear will be about 115 decibels several feet in front of the two speakers which are focused in the middle of the room here. Elsewhere in the room the noise level will vary from 105 to 110 decibels.

Going on with what you will hear so you will know what is going on a little better: After this first loud noise of engine ignition at lift-off, which is shown at the left of the chart up there and marked by the word "Launch," the noise level will then decrease fairly rapidly as the vehicle moved away from the ground reflecting plane. However, the aerodynamic boundary-layer noise then builds up to very high levels again as the vehicle flight speed increases. The noise level then decreases again as the vehicle moves out of the dense lower atmosphere. The recording lasts 2 minutes and will actually be played at noise levels I indicated previously.

Incidentally, there is a model of the vehicle on my right or on your left, Mr. Chairman, partly behind you, showing the Atlas launch vehicle and the Mercury capsule mounted on the nose. The noise recordings which you will hear were obtained inside the Mercury capsule at the position of the astronaut's head.

Will you go ahead. We will stop any time you indicate.

The CHAIRMAN. I will stop any time any member of the committee indicates.

[A taped recording of noises inside a Mercury capsule was played for the committee.]

Mr. ABBOTT. I would like to repeat that what you have heard is approximately the noise level that the astronaut will hear inside his protective helmet.

The CHAIRMAN. How much is that reduced?

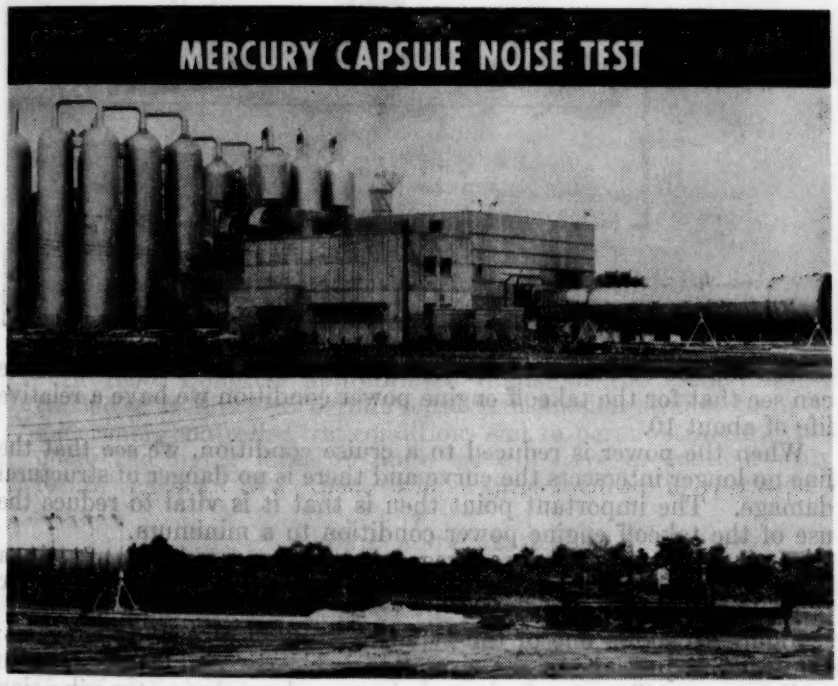
Mr. ABBOTT. That is reduced at least 10 decibels.

This recording has proven extremely valuable in our planning for the Mercury program in that we discovered that the noise levels were considerably higher than anticipated. We have used this recording as a basis for developing the insulation requirements for the astronaut's helmet and as a basis for the testing of the onboard equipment.

As a point of interest, I might mention that we found that one of our existing facilities, a high-temperature structures test facility, which is shown on the upper half of figure 8, had a high-speed jet exhaust which could be used effectively for such tests.

The lower half of the chart shows a picture of a model of the Mercury capsule being placed in position in the exhaust field for acoustic testing. We plan to use this facility to check out not only the instrumentation but also the astronauts.

FIGURE 8

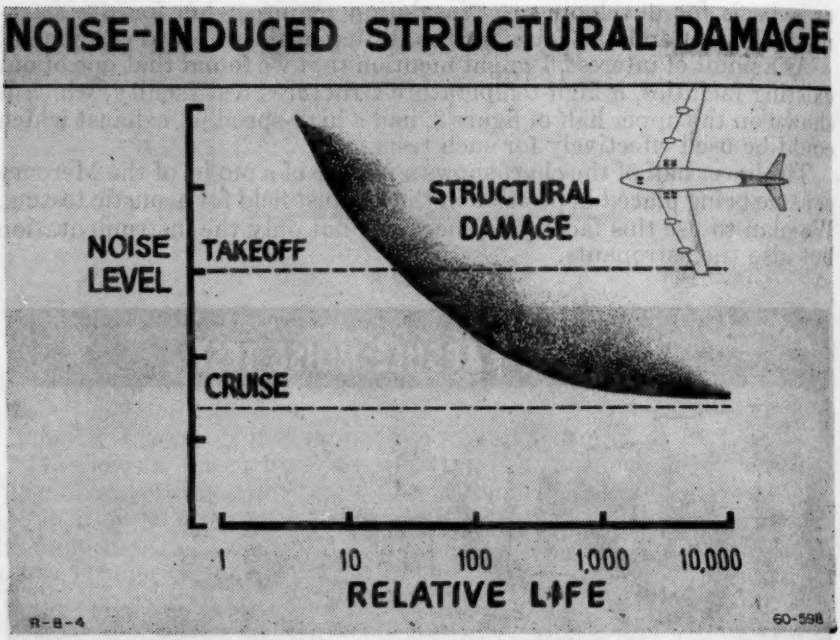


RESEARCH ON SONIC FATIGUE

I mentioned earlier that noise has been a serious factor in inducing structural damage. Figure 9 gives you some idea of the problem and shows an airplane in the upper right-hand corner. The shaded portions of the airplane, the wing trailing edge surfaces, the aft end of the fuselage, and the tail surfaces have been particularly prone to structural damage of a rather serious kind on a number of high-speed military airplanes.

The chart also shows a plot of the noise level against the relative life of the structure. This curve on the upper part of the chart

FIGURE 9



marks the life of the structure for the various noise levels. Thus we can see that for the takeoff engine power condition we have a relative life of about 10.

When the power is reduced to a cruise condition, we see that the line no longer intersects the curve and there is no danger of structural damage. The important point then is that it is vital to reduce the use of the takeoff engine power condition to a minimum.

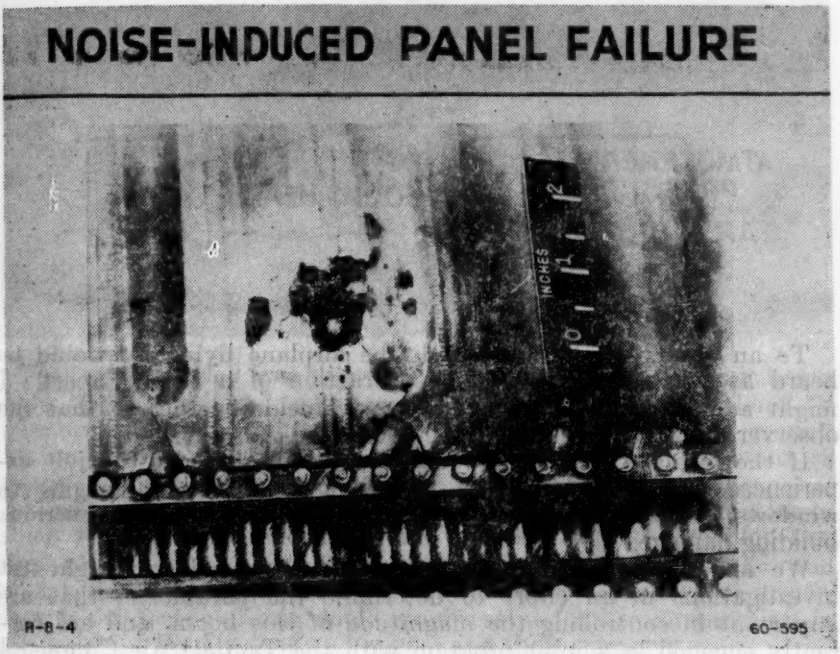
We have been actively engaged, at our research centers, in a number of studies aimed at finding solutions to this problem of sonic fatigue.

Figure 10 shows one of the typical results of a noise fatigue test; the fracture just above the rivet line is clearly visible here, and in addition you will notice the large hole gouged out due to the vibration of a small object that had been attached at this position.

I also have two test specimens that I would like to pass out to you now so that you can examine the character of the failures. One of these specimens is a honeycomb sandwich panel which has some advantage in regard to noise fatigue. The other is an early sample of a skin panel proposed for the Mercury capsule.

You can be sure that the flight vehicle skin will be more robust than this one was. By means of such test programs and by theoretical studies, we have aimed at developing methods of predicting the life of given structures. We have also aimed at devising structural arrangements, configurations, and methods of structural attachment that will be more fatigue resistant.

FIGURE 10

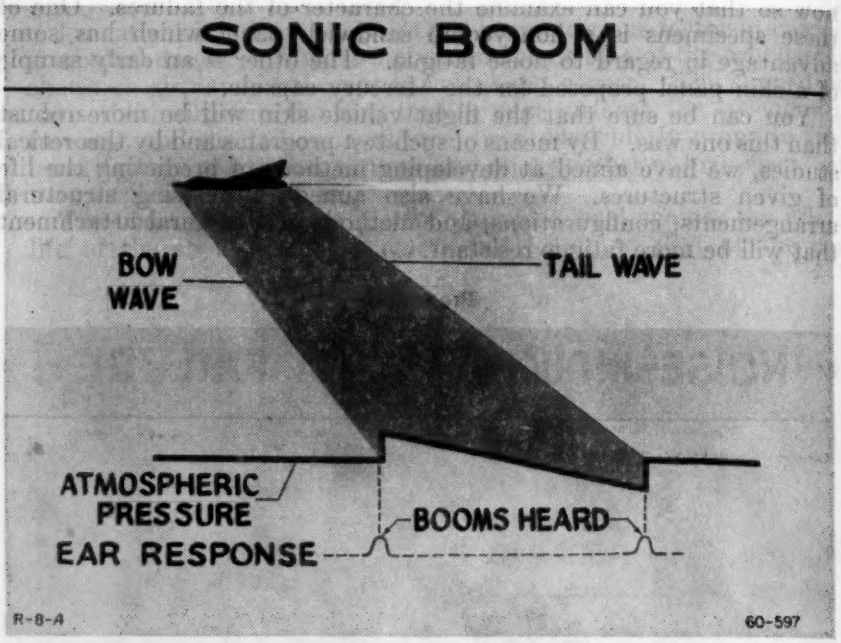


In 1960, Congress appropriated funds for the modernization of two noise facilities to permit noise transmission studies to be made under more controlled test conditions and to permit structural testing under the higher levels of noise we will have to contend with for future vehicles. We expect to have these facilities in operation very soon.

SONIC BOOM RESEARCH

As the last item, I should like to tell you a little about our research on the sonic boom. Figure 11 (p. 14), illustrates what we mean by the term "sonic boom." When an airplane is in flight at supersonic speed, large pressure bow and tail waves are generated which extend to the ground.

FIGURE 11



To an observer on the ground, the airplane flying by would be heard as two successive booms, a fraction of a second apart. I might add that these booms frequently meld together so that the observer apparently hears only one boom.

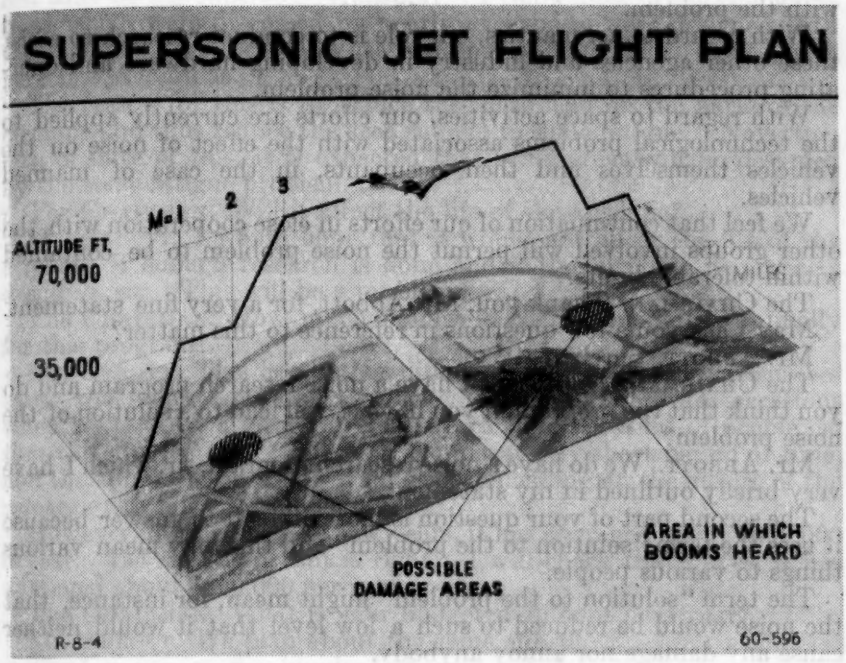
If the airplane flies by at sufficiently low altitude, the jolt experienced would be somewhat unnerving as well as damaging to windows, plaster, and would perhaps give rise to more serious building damage.

We have undertaken a number of wind tunnel and flight-test investigations in an effort to determine the parameters that are important in controlling the magnitude of this boom, and are currently engaged in a joint program with the Tactical Air Command and the Federal Aviation Agency involving flight tests of F–104, F–105, and B–58 airplanes in a study of intense sonic booms.

The sonic boom problem has important implications for the operation of supersonic transports. The last figure (fig. 12) deals with this problem and shows a typical altitude flight plan for a supersonic airplane cross-country flight.

As we can see, the airplane would take off from the ground, climb at subsonic speeds, and reach mach 1 at about 35,000 feet. The airplane would then level off and accelerate to mach 2 at this altitude. This is the critical part of the operation in regard to sonic booms. Then follows a climb to 70,000 feet and further increase of speed to mach 3. The airplane then proceeds at this altitude and speed until the letdown.

FIGURE 12



The large encircled area shows the region over which the sonic boom could be clearly heard. As indicated, it covers an area about 50 miles wide along the flight path. To an observer on the ground this sonic boom would sound much like thunder, either distant or nearby, depending upon how close he was to the flight path.

Also shown by the two small circled areas are the ground regions in which some damage such as glass breakage might occur for this flight plan. Because of this possibility, the altitude for acceleration to high-speed flight might have to be raised from 35,000 feet to perhaps 45,000 feet, and this would require some further compromises in the design of the airplane and engine and their efficiency.

CONCLUDING REMARKS

I have tried to outline the major noise problems in aeronautics and in our space program and have reviewed our current research activities on engine noise, boundary layer noise, the sonic boom, and structural fatigue induced by noise.

I should like to emphasize that these research programs are aimed at providing basic information on the magnitude and characteristics of these noise sources, on the basic principles for decreasing the level of engine and aerodynamic noise, and on techniques for alleviating their effects on structures and their annoyance to communities.

The NASA considers the noise problem to be a serious one. As in other technical areas, we work as part of a team which includes other Government agencies, the manufacturing and aircraft operating

industry, the scientific community, and other organizations concerned with the problem.

With regard to aeronautics, our role is to conduct research to assist these other agencies and industry in developing hardware and operating procedures to minimize the noise problem.

With regard to space activities, our efforts are currently applied to the technological problems associated with the effect of noise on the vehicles themselves and their occupants, in the case of manned vehicles.

We feel that continuation of our efforts in close cooperation with the other groups involved will permit the noise problem to be contained within tolerable limits.

The CHAIRMAN. Thank you, Mr. Abbott, for a very fine statement.

May I ask you a few questions in reference to this matter?

Mr. ABBOTT. Surely.

The CHAIRMAN. Does NASA have a noise research program and do you think that the program, if you have it, will lead to a solution of the noise problem?

Mr. ABBOTT. We do have a noise research program, sir, which I have very briefly outlined in my statement.

The second part of your question is more difficult to answer because it uses the term "solution to the problem" and this may mean various things to various people.

The term "solution to the problem" might mean, for instance, that the noise would be reduced to such a low level that it would neither cause any damage nor annoy anybody.

I, myself, cannot foresee such a fortunate outcome. However, I do believe that this research program, together with cooperative efforts by everybody else concerned, can contain the noise problem within tolerable limits. This is going to be a hard thing to do, but I do believe that it can be done.

The CHAIRMAN. Do you have, a close relationship with the engine and airframe manufacturers, designed to assist them in working out this problem?

Mr. ABBOTT. Yes, sir; we do.

Airframe and engine manufacturers serve on our various advisory committees so that we have formal coordination with them. In addition to that, there are constant contacts on the technical level between our experts and theirs.

A very large number of these contacts are made during the year; meetings both at our laboratories and at their establishments.

The CHAIRMAN. You gave us a demonstration of noise intensity which the astronaut will have to endure. Are you able to communicate with him under these circumstances?

Mr. ABBOTT. Yes, sir; we expect to be able to do so.

The CHAIRMAN. How do you expect to do that?

Mr. ABBOTT. By built-in receivers in the helmets. Much the same techniques that are used in airplanes.

The CHAIRMAN. Is sonic fatigue a major problem in designing the mach 3 transport?

Mr. ABBOTT. Yes, sir; I would say that sonic fatigue would be a major problem. And to a very large extent this problem will be alleviated by the configurations which are chosen for the supersonic transport.

You may recall the testimony during the hearings which you held last May on the supersonic transport. I think most of the configurations which were discussed by nearly everybody were designed with the engine nozzles located in the rearmost parts of the airplanes, with very few exceptions.

The reason for this is to reduce the noise field on the parts of the airplane and thus reduce the area subject to sonic fatigue. Nevertheless, in spite of this, it is expected that some areas will be designed by the sonic fatigue problem.

The CHAIRMAN. Will it affect the life of the airplane?

Mr. ABBOTT. I would hope that it would not affect the life of the airplane, if enough research is done and if the airplane is properly designed, sir. This will be a problem.

The CHAIRMAN. How much money is NASA budgeting annually for this program?

Mr. ABBOTT. This is a rather difficult question to answer, sir, because the amount varies from time to time. There are occasions when we take on a large program which involves a lot of people, so that the effort is very large, for a comparatively short period of time, and then on other occasions it falls off, depending on the nature of the research which is undertaken.

However, during the past few years, it has averaged about $600,000 a year. Let me see if that is right. I will check that. Yes, it has averaged about $600,000 per year.

The CHAIRMAN. What is your budgeted amount next year?

Mr. ABBOTT. We plan about the same effort.

The CHAIRMAN. Six hundred thousand dollars for noise research?

Mr. ABBOTT. Yes, sir. I might add that this amount which I am quoting is the operating effort and does not include special facilities which are being employed. Now, some of these run to considerably more money.

The CHAIRMAN. What is your relationship with the FAA in reference to the noise problem?

Mr. ABBOTT. Our relations with the FAA are very good on all problems. We have a committee between NASA and the FAA which considers these problems. Mr. Rhode, my Assistant Director for Research in this area, is one of the cochairmen of the committee. I believe Mr. Pyle of the FAA is the other cochairman. I can supply the names of the other members if you wish.

These problems are coordinated formally through this committee and informally through continuing contacts at the working level, which go on from day to day.

The CHAIRMAN. Now, your program is to scientifically work out a solution, if that is possible. What is the FAA program? Does it cover merely the application of the results? Is it also scientific?

Mr. ABBOTT. We are concerned, as you say, with the scientific aspects of the problem, and the FAA, of course, are intensely concerned with having scientific solutions and with knowing the results of the scientific work.

The FAA, of course, is primarily concerned with the problems that are associated with the question of noise on communities, the life of the airplanes, and such matters in relation to their regulatory responsibilities.

I think that the FAA will be testifying in this respect somewhat later before this committee; will they not?

The CHAIRMAN. That is right.

How long has that committee been in effect?

Mr. ABBOTT. Substantially since the beginning of NASA. It was set up in the early days after NASA was established.

The CHAIRMAN. Mr. McCormack.

Mr. MCCORMACK. No questions.

The CHAIRMAN. Mr. Fulton.

Mr. FULTON. The question comes up whether our present airports and airfields near cities will be obsolete when it comes to the mach 3 supersonic transport plane.

If what you say is true, that there is the 50-mile area within which there will be definite effects on the flight plan that you showed, wouldn't it get beyond the point of tolerance very quickly if we moved the speed up any nearer these populated centers? Aren't we going to have to look ahead either to building new airports away from cities and populated areas or find some way to have the increase in speed and decrease in speed controlled to a greater extent, regardless of these baffles that you are talking of?

Mr. ABBOTT. I am not sure about what the answer to this question really should be, Mr. Fulton. I think a great deal depends on events which are not very clear yet.

The 50 miles that you mentioned is of course the width of the area where the sonic boom is heard, and this occurs only when the supersonic transport is flying at supersonic speeds at a high altitude.

The noise there, providing the transport is flying at properly high altitude, will be, as I said, much like thunder, either distant or closeby. And whether or not in the long run this would prove annoying to people on the ground, I think, is a matter that only experience will show.

Mr. FULTON. We have knowledge of that experience from the gentleman from New York.

It is annoying, isn't it?

Representative BECKER. Terribly.

Mr. ABBOTT. Are you referring to the sonic boom or to the——

Representative BECKER. Both, sonic boom as well as the noise from the jet engines flying to and from Idlewild.

Pardon me, I think the people at Inglewood had the same identical thing with the sonic boom.

Mr. ABBOTT. Close to the airports we would expect the supersonic transport to be operated only at subsonic speeds and to maintain these subsonic speeds up to an altitude of somewhere between 35,000 and 45,000 feet, which would then reduce the severity of the sonic boom and prevent the occurrence of the sonic boom in the area near the airports completely. The noise one has to worry about then is the noise from the turbojet engines. These engines will be more powerful and there will be more of them per airplane than is presently the case in the subsonic jets.

I would hope that these engines would be of the turbofan variety, which would be less noisy per unit of thrust. What the outcome will be is a little hard to say, but I would hope that they would not be much noisier, if any, than the present subsonic jet transports.

As you know, at some airports which are being built, such as the Dulles Airport, very special attention is being given to some of the noise problems.

Mr. FULTON. It would mean that airports and physical facilities for the new type transports that are supersonic, as well as any great increase of traffic at present levels, really should be more than 50 miles away from the edge of any metropolitan area?

It would be quite a revision of our physical facilities in America, such as airports.

Secondly, as far as the military is concerned, it would seem to me they would have to be even farther away. We would have to have a different military posture than having the airports for military purposes ringing our cities because of this tremendous noise factor.

Mr. ABBOTT. The only reply I can make, sir, is that I am really not an expert on that aspect of the problem at all. I don't think my views on it would carry any particular weight.

Mr. FULTON. We have a jet airport near Pittsburgh in my district, which we will very gladly give away to anybody, because people in those areas are finding that the level of tolerance has been reached. That is all.

The CHAIRMAN. Would the vertical takeoff airplane alleviate this noise?

Mr. ABBOTT. I really do not know, sir.

The reason I reply in that manner is that I do not believe the vertical takeoff and landing aircraft or the steep takeoff and landing aircraft for that matter have yet been developed to the point where it is possible to visualize the nature of the aircraft or their mode of operation in such a way as to make any answer really possible.

I can visualize possibilities that it might make the noise either very much better or very much worse. It could go either way at the moment.

Representative BECKER. Mr. Chairman, would you indulge me, since I am not a member of the committee?

The CHAIRMAN. Does any member of the committee have a question?

[No response.]

The CHAIRMAN. All right.

Representative BECKER. In your testimony, both on the turbofan engine as well as your statement a minute ago, you used two different diagnoses. In the first instance you said that you hoped the turbofan engine would be less noisy than the present jet engine.

Mr. ABBOTT. Yes, sir.

Representative BECKER. Then, later, you said that the tests so far have not proved this to be the case.

Mr. ABBOTT. I said that the tests so far have shown that the noise reduction was not as great as expected. So it was somewhat disappointing.

Representative BECKER. How much of a difference would you say it was than what was expected?

Mr. ABBOTT. I don't have any figures on this before me. There was about a 10-decibel noise reduction expected, and if I could supply that information I would be happy to do so. I think it is something on the order of half.

Representative BECKER. The reason I ask is because we have had this testimony before the Armed Services Committee this past year,

and I wanted clarification as to the difference you thought might have been estimated.

Mr. ABBOTT. I would like to, if I could at the moment, point out that this result has been partly due to the siren-type noise from these fans and that we are conducting quite a program to find out more about this, and that the industry is also extremely active in this area, and that I think it is reasonable to expect a solution to this problem.

The CHAIRMAN. Does NASA have a coordinating committee with the military services, too?

Mr. ABBOTT. We have a great deal of coordination with the military services.

The CHAIRMAN. Are you coordinating this problem with the military?

Mr. ABBOTT. I believe that this particular problem has not been the subject of formal coordinating activity at the highest levels, such as by the Civilian-Military Liaison Committee, but there is continuing coordination at lower levels.

Several of our programs have been conducted in cooperation with the military. They have supplied us airplanes for our tests. We provide instrumentation and assistance in their tests. There is a thorough and complete exchange of information, and I think all of us are thoroughly familiar with what the other people are doing. I think the coordination is very good.

The CHAIRMAN. Would it advance the work by having a more formal coordination?

Mr. ABBOTT. I do not think so, sir. I think coordination is excellent in this area.

The CHAIRMAN. Now, is this problem holding back the Mercury program?

Mr. ABBOTT. No, sir; it is not.

The CHAIRMAN. Is the Mercury program being held back?

Mr. ABBOTT. I think you will appreciate, sir, that I am not responsible for the Mercury program, so I cannot speak authoritatively with regard to it.

However, it is my understanding from talking with those who are, from staff conferences on the subject, and from information of that type, that the Mercury program is proceeding extremely well and is not being held back.

The CHAIRMAN. It is proceeding just as scheduled?

Mr. ABBOTT. Essentially; yes, sir.

The CHAIRMAN. You are satisfied with the progress of the Mercury program?

Mr. ABBOTT. This is a hard question to answer. I am not dissatisfied with it, except in the sense that I am never thoroughly satisfied with progress in anything. I think this would be a rather sad state of mind to get ourselves into. We are continually looking for ways to improve and to speed these things up.

The CHAIRMAN. As long as the Soviets are threatening to get ahead of us on that program is why we feel misgivings about it.

Mr. FULTON. You have talked of the noise problems in flight. What has been done on the ground and on the takeoff. For example, on the warming up, on the runway, and on the low-level of ascent on takeoff, where they make a much longer run before they take a fast rise? What have you done on those three levels?

Mr. ABBOTT. These problems, sir, which are a little different than the direct scientific problems which I have been discussing and relate to some extent more to operational problems, and in some cases, such as the approach and takeoff paths, and in other cases to a provision of mufflers or sound barriers of one type or another on the ground, so that these do not fall specifically within NASA's area of research.

However, we have cooperated very extensively with both the military services and the FAA, with regard to supplying them with scientific information that they needed in order to proceed with their programs in these areas.

Mr. FULTON. Who is handling those programs, then, of warmup, taxiing, takeoff, and ascent?

Mr. ABBOTT. These are responsibilities of the military with regard to their operation and of the FAA with regard to commerical operation.

Mr. FULTON. Who should we get, then, to tell us of those programs from both the military and FAA?

Could you tell us either now or later——

Mr. ABBOTT. You desire names?

Mr. FULTON. If you will just tell us how to do it, I think we will ask the chairman to get somebody.

Mr. ABBOTT. I think this committee is going to hear from the FAA with regard to this. I do not know your plans with regard to the military. However, we would be very glad to discuss this problem with the staff.

The CHAIRMAN. We have General Quesada scheduled for Thursday and we have other witnesses from the military also.

Mr. FULTON. If we could give advance notice to the FAA and the military to be prepared on those particular points.

The CHAIRMAN. That is right. Counsel will look out after that.

Mr. FULTON. That is all.

The CHAIRMAN. Captain Silberstein, do you have any questions?

Captain SILBERSTEIN. No, sir.

The CHAIRMAN. Do you have any, Colonel Turner?

Colonel TURNER. No, sir.

Mr. MCCORMACK. Might I ask a question?

The CHAIRMAN. Certainly, sir.

Mr. MCCORMACK. How closely is the industry cooperating in this particular matter? You have referred to closeness, but give us more evidence.

Mr. ABBOTT. Yes. Just a moment and I will give you a few statistics.

To give you a general idea of the extent of this cooperation, I refer to the direct contacts and visits that have been made at the Langley Research Center's Acoustics Branch, which is a major group working on this problem now, although we do have other groups working on it, including those at other research centers.

This one group at Langley has had direct contacts in the last year, and in most cases more than one contact, with 16 aircraft companies, 12 governmental agencies, 5 consulting agencies.

I think the cooperation is excellent. They visit us, we visit them. There is complete exchange of information.

Mr. MCCORMACK. Do you know what money is being spent by any of these companies?

Mr. ABBOTT. I have no information on that, sir. It is certainly substantial in a number of cases. One might even say, for instance, that a large part of the costs for the developing of the new types of engines that I have mentioned might be attributed to the noise problem.

The CHAIRMAN. Any further questions?

If not, thank you very much for your fine statement.

Congressman Becker, who is here, would like to make a statement.

Representative BECKER. I spoke to you before the hearing. I would like to say that my natural interest in your hearings here is because of the work we have been trying to do through FAA, the New York Port Authority, in reference to Idlewild Airport. And anyone concerned with it knows that we have one of the most serious problems of noise of any airport in the country, and I am not minimizing any other.

Naturally, the development that may come from this is of intense interest to us because, after all, the reduction of noise through whatever direction it comes is a great necessity. Our people there have been suffering for the last several years, and more and more with the advent of the jets.

I know the FAA and General Quesada are doing everything possible. We are working with them. Whatever you do here will be of great interest.

The CHAIRMAN. Thank you. The gentleman is diligent. It is a problem that is not limited to Idlewild.

Representative BECKER. That is right. That is right.

The CHAIRMAN. We have the problem in Louisiana. I am sure they have the problem out in California, because we have any number of telegrams from the California area.

I daresay we have problems up in Boston and all over the United States. We appreciate the gentleman's cooperation.

Mr. MCCORMACK. I could testify to Boston, because I hear the noise when I am trying to go to sleep.

The CHAIRMAN. With that in mind, we will intensify the inquiry. [Laughter.]

The CHAIRMAN. The next witness that we have is Dr. Richard H. Bolt, Associate Director (Research), National Science Foundation.

Dr. Bolt, you are with the National Science Foundation. I think that you have a statement in written form.

Dr. BOLT. That is right.

The CHAIRMAN. I might say to the members of the committee that Dr. Bolt has a long and a distinguished record in scientific work.

If there is no objection, rather than reading his record, which is very fine, I would like to place it in the record.

Will you please proceed with your statement?

STATEMENT OF DR. RICHARD H. BOLT,[2] ASSOCIATE DIRECTOR (RESEARCH), NATIONAL SCIENCE FOUNDATION

(The prepared statement of Dr. Richard H. Bolt is as follows:)

The Outlook for Aviation Noise Control

THE NATURE OF NOISE

Noise is defined as unwanted sound. The word "unwanted" brings in the essential human element. Without considering the reactions of people we cannot solve a noise problem. But people can react in many different ways.

This might have happened in 1943: A flight of bombers roared over a small village, people ran out of their houses, looked up, and cheered. The boys were safely home from a bombing mission. Again, in 1950, those same bombers in a routine training flight, roared over the same village, at the same time of day, and those same people wrote violent letters of protest to the newspaper. Their peace had been disturbed. They were angry at the unwanted sound.

The first step in analyzing a noise problem, therefore, is to ask: By whom is the sound unwanted, under what conditions, and because of what effect? In engineering terms, this first step leads to the establishment of the appropriate criteria: the requirements that must be met in designing the measures for noise control. Corresponding to three general ways in which sound can produce undesired effects on people, there are three categories of noise control criteria:

Damage risk criteria that relate the intensity, frequency, and other relevant characteristics of noise exposure to the chance that the noise will damage the hearing mechanism and thus produce temporary or permanent hearing loss.

Speech interference criteria that relate the noise characteristics to the extent of speech interference produced by the noise; at high levels, noise can obliterate speech sounds completely; at lower levels, only a small fraction of the speech sounds may be lost to the listener—but this loss may lead to misunderstanding of instructions and even critical errors in performing tasks.

Disturbance criteria that relate noise characteristics and other relevant factors to the degree of disturbance; this complex human reaction may involve annoyance, fear, interference with sleep, intrusion of privacy, anxiety, anger, or other feelings that make the noise unacceptable.

These three categories of criteria cannot always be distinctly separated. Thus, a particular noise environment may interfere with speech and also produce annoyance and complaint, in which case more than one criterion must be used in analyzing the noise problem.

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[2] Richard Henry Bolt is Associate Director (Research) of the National Science Foundation, where he has been serving since January 1, 1960, on leave of absence from his post as professor of acoustics, Massachusetts Institute of Technology. He is also on leave from his position as chairman of the board of Bolt Beranek & Newman, Inc., Cambridge, Mass., a consulting firm founded in 1948.

Born April 22, 1911, in Peiping, China, where his father was medical director of Tsing Hua University, Dr. Bolt received a bachelor of art's degree in architecture from the University of California in 1933 and a Ph. D. in physics from that institution in 1939. He conducted doctoral research at the University of California at Los Angeles on wave-theory problems in acoustics. Under a National Research Council fellowship in physics, he continued his research in acoustics at MIT, 1939–40. He was then appointed associate in physics at the University of Illinois.

Returning to MIT in 1941, Dr. Bolt helped establish a defense research project in underwater sound, and served as its technical director during 1942. Transferring in 1943 to the OSRD, he served as its scientific liaison officer in subsurface warfare, in London. From early 1944 to the end of the war he was chief technical aid for division 6 of the National Defense Research Committee.

In 1945 he returned to MIT and established the acoustics laboratory which he directed until 1957. During 1957–59 he was principal consultant for the Biophysics and Biophysical Chemistry Study Section of the National Institutes of Health.

Dr. Bolt served as the first Chairman of the Armed Forces-National Research Council Committee on Hearing and Bio-Acoustics (CHABA), 1953–55, and was also chairman of the panel on Submarine Noise Control, Committee on Undersea Warfare, NAS–NRC. He was a member of the Subcommittee on Aircraft Noise, NACA, 1953–57, and a member of the Committee on Operating Problems of the NASA during 1959.

In 1949–50 he was president of the Acoustical Society of America, of which he is a fellow and from which he received the biennial award in 1942. He was president of the International Commission on Acoustics from its establishment in 1951 to 1957, and president of the Second International Congress on Acoustics in 1956.

He is a fellow of the Acoustical Society of America, a fellow of the Physical Society, a senior member of the Institute of Radio Engineers, a member of the governing board of the American Institute of Physics, and a fellow of the American Academy of Arts and Sciences. He has received Phi Beta Kappa, Sigma Xi, Eta Kappa Nu, and other honors, and is a member of the Cosmos Club.

He is coauthor of the book "Sonics" (John Wiley & Sons, 1955); coeditor of "Biophysical Science—A Study Program" (John Wiley & Sons, 1959); author of a chapter in the "Handbook of Noise Control" (McGraw-Hill, 1958); and author of numerous scientific and engineering publications relating to noise control and other aspects of acoustics.

Noise can also produce undesired effects on physical objects. But the human element is always present. For example, people become very much concerned if intense noise damages the structure of an aircraft.

Of course we can, and do, develop criteria that relate the amount and character of noise to the mechanical effects it produces on equipment, structures, and electronic devices.

In the last analysis, however, it is people—not physical objects—that care. It is a matter of engineering or economic judgment as to what tolerances are allowable in the degradation of performance of a piece of equipment. Having agreed on the desired performance, one can then establish the required limits on the noise environment in which the piece of equipment is to operate.

THE NOISE SYSTEM

In any case, establishment of criteria is the first stage in the rational analysis of any noise problem. Next, one must analyze the sources of the noise—the various points at which mechanical vibrations, airflow, impact of metal parts, and so forth, generate the noise. This is largely a matter of acoustical engineering, in some cases today quite routine, but perhaps with a strong assist from mathematics, physics, mechanical engineering, aeronautical engineering, or other fields.

The third general stage of noise analysis is to determine the many paths along which noise "flows" from the sources to the receivers of the noise, be they people or equipment. Usually there are many such paths. It is not enough to close the front windows if noise is still coming in the rear windows. It is not enough to muffle the exhaust stack of an aircraft engine test cell if appreciable noise is leaking through cracks and doors. This phase of the problem—the calculation of all the paths and their relative contributions—often turns out to be a large-scale sleuthing job, tracking down the many ways in which sound energy can escape and intrude. But the underlying principles are reasonably well understood, and the well-equipped acoustical engineer knows how to tackle the problem.

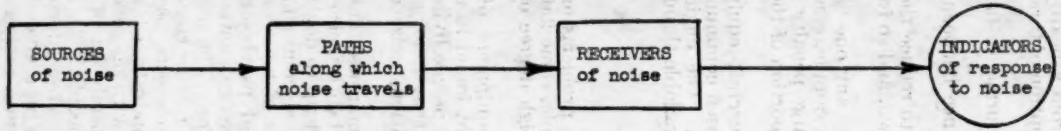
The final stage of noise control is synthesis: bringing together all the information regarding the sources, the paths, the receivers, and the criteria that specify what noise is "acceptable"—and then designing a suitable solution. It must be suitable in many ways: it must produce an acceptable situation for those on whom the noise is impinging, and it must also be an operationally and economically feasible solution.

The synthesis of a suitable solution is greatly aided by the concept of the noise system. As outlined in the accompanying diagram, this system represents the flow of noise energy from sources, through paths, to receivers, and the measurement of receiver responses by an indicator ("meter") that can be checked against the applicable criteria.

(The diagram referred to is as follows:)

THE NOISE SYSTEM

(Here "NOISE" means any undesired sound, vibration, or shock wave)



Aircraft engines
propeller, turbojet, ram jet, rocket, etc.

Air flow
boundary layer, ventilation, etc.

Equipment
turbines, hammers, drop forges, grinders, etc.

Sonic boom

Outdoors
through foliage, around obstacles, low over ground, high in air, etc.

Indoors
through walls, through windows, along corridors, through ducts, etc.

Structures
aircraft skin, equipment supports, test cell stacks, engine mounts, etc.

People
working, conversing, relaxing, convalescing, sleeping, traveling, reading, etc.

Equipment
aircraft structure, control device, electronic part, windows, etc.

Hearing loss
All degrees, both temporary and permanent.

Speech interference
All degrees, up to complete masking of conversation.

Disturbance
Complex feelings of annoyance, fear, intrusion, economic loss, etc.; expressed by complaint or action, or unexpressed.

Malfunctioning and damage
structural fatigue, component breakage, unreliability, window fracture, etc.

(All categories contain further subdivisions and many additional examples.)

CRITERIA for noise control relate responses to physical characteristics of noise exposure.

The system diagram for an actual problem usually contains many blocks, to represent several sources, paths, and receivers, joined by a complicated network of interconnections. Each block is assigned appropriate numbers (in watts, decibels, cycles per second, and so forth) and the performance of the entire system is calculated.

Then the engineer is in a position to propose possible solutions and predict their consequences. Each proposed solution is represented by a set of adjustments of different parts of the system.

Consider, for example, the following problem. Noise from aircraft operations on and near an airport gives rise to widespread complaints from a nearby community in the town. A possible solution might call for the adoption of three noise control measures:

(1) Require the aircraft to carry a muffler of specified performance (a source adjustment);

(2) Alter the flight patterns to increase the average distance between flying aircraft and the community (a path adjustment);

(3) Inform the community that measures are being taken to reduce the noise per se, that the airport brings valuable new business to the town, and so forth, as appropriate (a receiver adjustment).

Many aircraft noise problems are too severe to be solved by any one "adjustment." The noise from a present type turbojet engine, for example, cannot be "muffled" by more than a few decibels without incurring a large penalty in performance. Each part of the system must carry a reasonable portion of the noise control.

The several interests—manufacturers and operators of aircraft equipment, airport planners and operators, and the residents of noise-exposed communities—must work together toward sharing the burden equitably. The engineering techniques needed to guide such cooperative efforts are now available through the analysis of the noise system, along the lines indicated above.

EMERGENCE OF NOISE CONTROL

Until recent decades, man has been able to handle his noise problems more by intuition than by science. During the last century, for example, some flats were built with massive, double-construction walls to provide a high degree of noise isolation between adjacent families.

Then our technology began to produce machinery and equipment of great power and high speed, devices that generated many noises not found in nature. Workers in heavy industry, drivers of trucks and tanks, and people living near factories and railroads began to experience high levels of noise that annoyed them and interfered with their work. To provide needed alleviation, noise control emerged as an engineering specialty.

Noise engineering came of age during World War II. Submarines, tanks, aircraft, and other military vehicles produced noise that interfered with their combat missions. Several research and development projects were set up to devise suitable methods of noise control, to improve the performance of communication systems in noisy environments, and to study stressful effects of noise on men. The scientific backlog of relevant knowledge in physics and psychology was rapidly depleted and a host of new problems and gaps in knowledge showed up.

The close of the war saw an upsurge of interest in acoustics. The needs for basic research and for more refined engineering techniques in noise control attracted the attention of a number of physicists, engineers, architects, psychologists, and others in several universities and Government and industrial laboratories. Their programs covered a wide range of problems dealing with the generation of sound, the measurement and analysis of sound, the transmission of sound through gases, liquids, and solids, and the effects of sound on people.

During the last 15 years, the order of $20 to $25 million has been devoted to basic research relevant to noise. The bulk of the support has been given by the Armed Forces and the NACA–NASA, who have had intramural programs and have sponsored research in such universities as Brown University, Catholic University, Columbia University, Harvard, University of Illinois, Massachusetts Institute of Technology, University of Michigan, University of Minnesota, Pennsylvania State University, University of California at Los Angeles, Washington University, and others.

The National Science Foundation has granted, since its establishment, about three-quarters of a million dollars for some 30 basic research projects on subjects relevant to noise and its effects on people. Although for the most part these studies were not motivated directly by noise problems, they are likely to yield

a better understanding of noise and of its effects on people, and thus to strengthen the engineering approaches to these problems. (See app. A.)

STATUS OF RESEARCH

Just where do we stand in scientific and engineering research relevant to this field? First, regarding paths in the noise system, the scientific literature now contains a well-rounded body of information about the transmission of sound through gases, liquids, and solids.

Many special studies have been done on sound propagation through inhomogeneous media, such as the atmosphere and oceans. (Research in underwater sound contributes backup knowledge pertinent to airborne sound.) Although there are still many unresolved fine points, such as the specification of meteorological data for use in predicting sound propagation through the atmosphere, and further research on many such points should be encouraged, the state of knowledge regarding sound transmission is not a bottleneck in the solving of aviation noise problems.

The situation regarding sound sources is about the same. The major conceptual breakthrough here was a theory, put forth by mathematician Lighthill of England, that describes the generation of noise by turbulent motion in a fluid.

Lighthill's theory, extended by several other scientists, makes it possible to estimate rather well the amount of noise that is produced by the exhaust stream of a jet engine.

Again, there are many scientific fine points that need clarification. In general, however, our ability to handle noise problems is not limited significantly by lack of knowledge regarding the basic physical principles of sound generation—though much more could be done in applying this knowledge to the design of propulsion systems.

Regarding noise receivers and criteria, two aspects are reasonably well understood. The way in which noise interferes with speech has been thoroughly analyzed and we have quantitative criteria for calculating the percentage of speech intelligibility for person-to-person communication in almost any describable noise environment.

Also, the effect of noise in producing hearing impairment in humans is fairly well established. We have criteria that set safe limits on long-duration exposure of man to steady noise. Criteria for short-duration and impulse-type noise need and are receiving further study.

Preliminary standards relating noise exposure to hearing impairment have been set forth in documents by the American Standards Association, the Armed Forces, and other organizations.

The general problems of "disturbance," on the other hand, are more difficult and are less well understood. The degree to which a person is annoyed by noise depends not only on the characteristics of the noise he is hearing at the time, but also on the past history of his noise exposure, on his knowledge about the source of the noise, and on a wide range of psychological, social, and economic factors. In some respects, disturbance by noise is like disturbance by any other means that produces stress, intrusion of privacy, fear, worry, interruption of sleep, and the like.

Thus any basic research that bears on these complex responses of people to external stimuli may help us better to understand these responses to noise. A number of the research programs listed in appendix A relate to these psychological and physiological problems, and there is a large body of literature pertaining to this subject.

Nevertheless, the most knowledgeable specialists on bioacoustic problems agree that there is much more to learn and that we do not have an adequate understanding of complex human behavior.

When noise involves a group or community of people, not just one individual, the problems become vastly more complicated. Whether or not a given community organizes to complain against noise, such as noise from air operations, depends not only on individual reactions but also on the emergence of group leadership, on the extent to which the leaders are familiar with ways in which to register complaints and to organize further action, and on other social factors. These basic problems in social and psychological science are inadequately defined and still await thorough scientific investigation.

Meanwhile, useful progress has been made by opinion surveys and empirical studies of community response to noise. The results from these activities, supplemented by recent research on perceived noise levels, form the basis of the

criteria now available for estimating the nature and magnitude of community reactions to noise exposure.

The National Opinion Research Center, under NACA sponsorship, conducted opinion polls in eight cities containing major airports. Reactions of thousands of residents, living at different distances from the airport, were sampled and at the same time physical measurements were made on the noise conditions in the community.

Subsequently, under Air Force sponsorship, the NORC conducted studies in communities neighboring on military airbases. These studies were aimed at establishing basic principles and relevant variables in the complex reactions of communities.

The engineering criteria now in use for predicting expected responses of people in communities are derived from empirical evidence from scores of case histories. The evidence shows that the vigor of response (complaint or other action) depends on a large number of variables, including intensity and frequency spectrum of the noise, number and duration of exposures, time of day or night, season, economic level of community, type of activity (sleep, reading, listening to TV, and so forth) that is interfered with, and past experience of the community with the noise.

Taking such variables into account, the engineer can use the criteria to predict with reasonable accuracy the likely reactions to any proposed aviation facility or operation. Such engineering analyses have proven useful and reliable in guiding the planning of many airbases and airports.

Responses of equipment to noise and vibration have been studied but still raise some unanswered scientific questions. There is today a great deal of activity in engineering research on damage, fatigue, and malfunctioning of structures, electronic components, and control systems exposed to intense noise and vibration.

These efforts could be more effectively carried out if we knew more about the underlying acoustical and mechanical interactions and the solid state physics at the atomic and molecular level.

Thus, some of the work in materials research, which is now receiving increased national attention, may be expected to improve our understanding of the effects of intense noise on aircraft and missiles.

CONCLUSION: WHAT IS NEEDED

The public impact of noise from present and future jet and rocket engines is becoming too severe for these problems to be solved just by the reduction of noise at the source.

Yes, some further progress can and should be made by applying full scientific knowledge to the design of the engine itself and to muffling devices. But at best, the noise from these powerful sources, when off the ground, can be reduced by only a small margin without incurring severe penalties in performance. (When on the ground, jets and rockets can be muffled to almost any extent—limited only by dollars.)

Likewise, some reduction of adverse reactions can be achieved by better public understanding of the sources of noise and of the reasons for increased aviation, both civil and military. But again, good public relations and public understanding can go only so far. Except in extreme national emergencies, the public (of a democracy) cannot be expected to accept noise disturbance beyond some reasonable limit.

We must face the facts. Science offers no panacea for protecting communities against aviation noise. A "quiet" jet engine is impossible. But science shows what can be done and provides the knowledge for doing it.

Major advances will require nationwide planning for aviation facilities, airports, airlanes, surrounding rural and urban areas, and compatible flight operations. Although it must incorporate scientific information, such planning is not a subject of scientific research: it is one of national understanding and coordinated action.

There are many interests involved and one cannot expect to find any solution to aviation noise problems that will be 100 percent agreeable to all interests. Everyone must give and take, accepting some restrictions on aircraft operations, some reallocation of land, some willingness to put up with more noise than might otherwise seem fair.

Yes, this is a big order—but the costs and difficulties of solution are fully justified by the potential benefits of future aviation.

(App. A, above referred to, is as follows:)

Appendix A

National Science Foundation Support of Research Relevant to Noise Problems

During 1953–60 the National Science Foundation has granted about ¾ million dollars for studies bearing on the generation, propagation, and measurement of sound, and on responses of living systems to sound and stressful stimuli. Although most of these studies were not motivated by specific interest in practical problems of noise, all of them yield knowledge that may contribute to the solution of such problems. Actually, some of the supported research has already increased our understanding of aviation noise problems and has furthered the train- of specialists competent to deal with this complex subject.

Through the Division of Mathematical, Physical, and Engineering Sciences, the Foundation has granted about $250,000 for the 13 studies listed below:

Research Instrumentation for a Sound Spectrograph, G. E. Peterson, Speech Research Laboratory, U. of Michigan.

The Production of Acoustic Transients, J. R. Cox, Jr., Central Institute for the Deaf.

Sound Propagation in Mocing Media, R. F. Lambert, Dept. of Electrical Engineering, U. of Minnesota.

Acoustic Analysis of Speech Sounds, M. Halle, Research Lab. of Electronics, Mass. Inst. of Technology.

Methods for Producing Uniform High Intensity Ultrasonic Fields, W. J. Fry, Dept. of Electrical Engineering, U. of Illinois.

Musical Acoustics, H. J. Fletcher, Sr., Dept. of Physics, Brigham Young U.

Sediment Attenuation of an Ultrasonic Plane Wave, G. H. Flammer, College of Engineering, Utah State U.

Diffraction of Light by Ultrasonic Waves in Transparent Solids, E. A. Hiedemann, Dept. of Physics & Astronomy, Michigan State U.

The Properties of Orchestral Reed Instruments, J. Backus, Dept. of Physics, U. of Southern California.

Dynamics of the Cochlea, H. J. Fletcher, Jr., Dept. of Mathematics, Brigham Young U.

Effects of Sound on Boundary Layer Transition, F. N. M. Brown, Dept. of Aeronautical Engineering, U. of Notre Dame.

Ultrasonic Study of Defects in Solids, J. Truell, Metals Research Laboratory, Brown U.

Precision Measurement of the Velocity of Sound in Gases, D. Bancroft, Dept. of Physics, Colby College.

A better understanding of the effects of noise on man is expected to accrue from studies on noise and vibration interactions with humans and animals, on psychophysiological aspects of stress, and on certain features of stimulus-response behavior. Through its Division of Biological and Medical Sciences, the Foundation has granted about $500,000 in support of the 20 such studies listed below:

Neurophysiological Processes in the Auditory Cortices, N. B. Gross, Dept. of Psychology, Lehigh U.

Physiological Mechanisms of Binaural Perception, M. R. Rosenzweig, Dept. of Psychology, U. of California, Berkeley.

Role of Binaural Time Differences in Reception of Speech, E. D. Schubert, The Cleveland Hearing and Speech Center.

Neural Quantum Theory of Hearing, J. F. Corso, Dept. of Psychology, Pennsylvania State U.

Exploratory and Fear Behavior in Lower Mammals, K. C. Montgomery, Dept. of Psychology, Yale U.

Investigations of Human Reactions to Stress, A. F. Ax, Dept. of Psychiatry, U. of Washington.

Psychophysical Parameters of Vibratory Perception, C. E. Sherrick, Jr., Dept. of Psychology, Washington U.

Influence of Stress on Behavior, W. R. Thompson, Dept. of Psychology Wesleyan U.

Studies of Auditory Pattern Formation, W. R. Thurlow, Dept. of Psychology, U. of Wisconsin.

Study of Auditory Localization, P. D. Coleman, Dept. of Psychology, Tufts C.

Research on Speech Perception, W. A. Rosenblith, Dept. of Electrical Engineering, MIT.

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Stimulus Patterning in Learning, W. W. Grings, Dept. of Psychology, U. of Southern California.
Methodological Study of the Aversive Properties of Stimuli, B. A. Campbell, Dept. of Psychology, Princeton U.
Perception of Sequential Stimulation, F. Attneave, Dept. of Psychology, U. of Oregon.
Reinforcing Properties of Auditory Stimuli, G. W. Barnes, Dept. of Psychology, U. of Maine.
Behavioral Analysis of the Auditory Pathways, J. M. Harrison, Dept. of Psychology, Boston U.
Perception of Periodicity in the Auditory System, A. M. Small, Jr., Dept of Speech Pathology & Audiology, State U. of Iowa.
The Construction of Sensory Scales, S. Smith Stevens, Psychological Laboratories, Harvard U.
Research on Speech Perception, K. N. Stevens, Dept. of Electrical Engineering, MIT.
Auditory Pattern Perception, M. D. Arnoult & W. H. Manning, Dept. of Psychology, Texas Christian U.

An International Conference on Audiology, supported primarily by a grant from the National Science Foundation, was held at the Central Institute for the Deaf and Washington University, St. Louis, Missouri, May 13–16, 1957. The 260 attendees from 30 countries were specialists in audiology, speech pathology, otolaryngology, psychology, physiology, acoustics, and related fields. The program of 30 papers and many panel discussions presented problems and research results in normal and abnormal functioning of speech and hearing mechanisms.

Of particular relevance to noise and its effect on people was a session on Hearing Loss and Noise Exposure, with the following papers:

Noise in Industry, J. R. Cox, Jr., Acoustics Laboratory, Central Institute for the Deaf, St. Louis, Mo.
Hearing Loss in Industry, A. Glorig, Subcommittee on Noise in Industry, American Academy of Ophthalmology and Otolaryngology, Los Angeles, Calif.
A Laboratory Method for the Study of Acoustic Trauma, D. H. Eldredge, Central Institute for the Deaf, St. Louis, Mo. and W. P. Covell, Washington U. School of Medicine, St. Louis, Mo.
Diagnosis, Susceptibility and Presbycusis, G. Hoople, University of the State of New York Medical School, Syracuse, N.Y.
Ear Protection, J. Zwislocki, Psycho-Acoustic Laboratory, Harvard University Cambridge, Mass.
The Establishment of Criteria Based on the Concept of Noise Exposure, W. A. Rosenblith, Massachusetts Institute of Technology, Cambridge, Mass.

The proceedings of the Conference are published in a special issue of the journal, The Laryngoscope, Vol. LXVIII, March 1958 (640 So. Kingshighway, St. Louis 10, Mo.).

Dr. BOLT. Thank you, Mr. Chairman. It is an honor to appear here before this committee.

I am especially grateful to have this chance to talk with you about a problem that I have been very deeply concerned with for some 20 years.

At first, when I ran into problems of noise control as a research scientist, I recognized, and many of my colleagues in the field of acoustics recognized very challenging basic research problems, and a great deal of fundamental work in a number of areas of science was started 20 years ago and more.

Later, some of us became interested in the more practical problems of applying this knowledge into specific engineering problems that were being met in the field, problems of reducing noise from aircraft on the ground and in the air.

And then some of us began to realize that the problem of aviation noise was really going to grow to very great magnitudes. And it seemed to us that every time a new scientific advance gained a few decibels, to speak loosely, the increased power and speed of aviation

more than swamped out the gains, and we realized that something different from the usual classical methods of solving noise problems was going to be needed.

During the last several years many of us in the field of acoustics have tried to develop new concepts, new ways of looking at the problem, that would help us to break through this rapidly and increasingly difficult situation we were facing.

It seems to me that your hearings are most timely just now, and I should like to commend the committee for taking this serious interest in the problem.

In addition to being at the present time with the National Science Foundation on leave of absence from MIT, I am also on leave from an engineering firm, and the president of that firm, Dr. Beranek, was invited to be with you today, and he has submitted written testimony. Unfortunately, he was stricken with appendicitis a few days ago and it was all the doctor could do to keep him from being here, because Dr. Beranek was looking forward to being with you.

However, your committee has very graciously accepted two other witnesses who can speak on some of the detailed engineering problems, and these two gentlemen are with me, Dr. Kryter, who has done pioneering work in studying perceived noise levels and effects of noise on man, and the other is Mr. Laymon Miller, who has headed up our engineering work on a number of airports in this country and abroad.

I should like to suggest that I speak only a very few minutes now, just pointing up highlights of my written statement.

Then I should like to introduce Dr. Kryter and then Mr. Miller, each of us talking about 10 minutes, and I would appreciate it if we could give the three presentations in a row. We have tried to design them as a unified package that would make the subsequent discussion a little more fruitful.

The CHAIRMAN. That will be fine.

Dr. BOLT. Then all three of us would be available to talk to the questions as you raise them.

Mr. FULTON. Coming from Pittsburgh, where we have the Pirates, we would ask that the batting average be enclosed, too.

The CHAIRMAN. However, they are from Massachusetts, both of them.

[Laughter]

The CHAIRMAN. Doctor, that arrangement will be fine.

Dr. BOLT. Thank you.

I am going to mention two or three highlights of my written testimony. The first one you will see in almost every paper written on acoustics, and yet it bears repeating and repeating.

The key point about noise is that it is defined as "unwanted sound," and that the first thing one has to do in looking at a noise problem is to try to understand who doesn't want the noise and why he doesn't want it, and under what conditions he doesn't want it. And this is the most difficult part of the science and the engineering.

Once we really understand what this noise, the sound, is doing to people, how they are reacting to it, then we can begin to go on with working out engineering problems.

And to point out just how this aspect of the problem, the effect on people, really ties in with the whole noise problem, we have prepared

a chart on page 25. I believe you have this in front of you. And, as a matter of fact—do you have a copy of that?

The CHAIRMAN. Yes.

Dr. BOLT. This one page is really a shorthand summary of the entire field of noise control. And I thought it would be useful here to serve several purposes. One is that we can talk about the relevant kinds of basic research in terms of the different parts of the system, and also we can bring out what kinds of solution are possible and what kinds are not possible in this whole problem of noise.

In a nutshell, there has to be a source of the noise and that is shown as a block in the diagram. This may be many sources, it may be many aircraft, many machines in industry, many hammers and so on.

These sources of noise send noise energy through paths, many kinds of paths along which the sound is transmitted, through the atmosphere, through windows, ducts, and so on. Then this noise impinges on receivers, on a man or on a piece of equipment, and then this receiver reacts somehow.

If it is a man and the noise is impinging on him, one reaction may be that he can no longer hear and understand what someone is saying next to him. Another possible reaction is that if he is subjected to this noise for a long period of time and if the noise is sufficiently intense, he begins to lose hearing sensitivity.

Now, the indicators to the type of response shown in the last column are things that we have to learn to be able to measure if we are going to do any real engineering on this field. And, as a matter of fact, in brief, the way one approaches an engineering noise control problem, whether it is to quiet an electric typewriter or to quiet a whole airport, is by breaking the problem down into these components and calculating from these sources, going through these paths, just how much noise will hit the receivers, perhaps the people in their homes around the airport; and starting at the other end, with criteria which we have attempted to set up, pick the criterion which will relate the amount of noise to the allowable reaction.

If these two come out to be different numbers, then the difference between them is what one has to gain through noise control. A very important point shows up when we look at noise as a total system problem.

I might have drawn little knobs on each of these squares representing control adjustments. On the first one, on the sources of noise, the knob adjustment might represent putting on a muffler that will take 10 decibels off the noise source. This is one way to help solve the whole problem.

Looking at the next block, the paths, I know that in general as the source gets farther away from the receiver, the noise gets less intense. So if, for example, in an airport noise problem, there was some way to double the height of the plane, I will gain some number, perhaps on the order of 6 decibels or so, although there are other quantities that measure this more meaningfully, and here then would be another 6 decibels added on to the first 10. Then finally at the receiver end, and this has been one of the interesting parts of the field—let me just mention one story:

If you were walking along Niagara Falls with someone whom you had just married and enjoying your honeymoon, this is a pretty wonderful experience, and the 110 decibels of noise surrounding you

certainly doesn't detract from it. In fact, perhaps it adds to it, because you have the sense that you two are there together and no one else can hear you, and so on.

Now, consider a second example. It is after midnight—maybe 2 a.m.—maybe a hot, sticky night, you are lying there tossing on your bed, and then [indicating sound], and you slap and so on—and here is 20 decibels of mosquito sound that is driving you nuts and keeping you awake.

There is a lot more than just the intensity of the sound that determines the effect of noise on people.

[Laughter.]

Dr. BOLT. This is one of the lessons we have had to learn the hard way. This means there is also such a thing as making a noise control adjustment on people, if you want to use these words. For example, if you hear a sound and you don't know what it is, it startles you, it scares you, you aren't sure you like it. When you fully understand the source of the sound and it has been explained to you, its need, your tolerance changes a great deal.

Recognizing this and explaining to the public the meaning and nature of noise, its relation to aviation and so on, can and has helped this problem. However, there is a definite limit beyond which no matter how much you know about the noise, you don't want to keep taking it, because it is interfering with other functions of life.

Now, one of our most difficult basic research problems is to try to study this very complex and subtle behavior, how do individuals and communities of individuals react to stresses, not only noise but other types of stresses. And what are the factors that determine whether or not they are going to complain and how strongly they are going to complain.

These are problems for basic research in psychology, in human factors, in other aspects of biological and social sciences.

Now, I should like to mention very briefly what the National Science Foundation has supported. During the last 8 years the Foundation has supported about three-quarters of a million dollars of basic research; some 30 projects.

Now the Foundation has never had a program, as such, on noise or noise control.

But when you look through the names of basic research projects that have been supported, you find many that contribute to the understanding of noise. This is a very nice example of the way in which a broad fundamental program of research, trying to get facts and understanding about many fields of science, can give you reservoirs of knowledge from which you can pull information and apply it to this problem, or this one, or this one.

And listed as an appendix here are some 30 basic research projects which were motivated by desire of various people to learn more about how sound is generated, how it is transmitted, its effects on people, and all of these research projects have contributed and are contributing to our knowledge in the field.

The CHAIRMAN. Now, who has worked on those 30 basic research problems?

Dr. BOLT. Mr. Chairman, as listed in appendix A of my statement, this research has been conducted by investigators at many places including the University of Michigan, Central Institute for the Deaf in

St. Louis, University of Minnesota, MIT, Illinois, Brigham Young University, Southern California, Notre Dame, University of California, and so forth. They spread right across the country, in many university centers.

These are basic research programs by professors and students in our academic centers.

Mr. FULTON. Mr. Chairman, I have to go to another meeting. Could I have just two short questions?

The CHAIRMAN. Have you completed?

Dr. BOLT. Yes, sir. I was ready to introduce the next speaker to pick up the story from here.

The CHAIRMAN. All right, Mr. Fulton.

Mr. FULTON. When noise obviously is the exciting of particles and the waves that are then generated through the original excitation of a group of particles, has there been any research done on the effect of magnetic fields?

That is the first question. Now if you excited particles by a magnetic field or held them in a certain magnetized area, has anything been done to check what might be the effect on noise in that area?

Secondly, where a vacuum—and I imagine the greater the vacuum the less the noise—has there been anything done in the way of configuration of, maybe, shields or vanes, that might be causing a partial vacuum so that the noise would come first into a vacuum before it came into the place where it could generate a wave that turned into a sonic boom?

Dr. BOLT. These are both extremely interesting questions. Let me take the first one, the magnetic effects.

It is true that if you have a gas, for example, in which the atoms and molecules have certain charge properties, electrical properties, and you run them through a magnetic field, that you can cause these particles to stream along just by the magnetic interaction.

It is also true that you could at the same time put sound waves or motion of various kinds into the gas.

Now, the combination of these two things I have just described is related to magnetohydrodynamics, which is a rather exciting basic research subject today, and also is going to have some relevance we believe in outer space and astrophysics.

However, if you try to think about this possible interaction and the way you could use it, say here on the ground, and for airplanes and so on, it is hard to think of a practical way to apply this concept. I don't know of anyone who has.

It is an interesting thought. Perhaps we should think a little bit harder about it. There may be some detailed ways in which this interaction could be used, but I know of none.

The second question about vacuums also is quite interesting and this is one we have used. Perhaps you recall the classical demonstration of sound waves in a classroom back in high school or something, a jar, and a bell inside, and you hear the bell and then a vacuum pump starts sucking the air out of a jar, and pretty soon it is a vacuum and you hear nothing.

In the design of test cells in the earlier days of development of our aircraft engines there was quite a problem of how to build a door that you could easily open and close to take the engine in and out and still keep too much sound from leaking around the door.

One of the solutions that was used in some test cells was to have a pair of doors that easily slid in place and then a vacuum pump was put on and the air sucked out between the doors and the doors drawn together very tightly.

Perhaps this airspace wasn't a very hard vacuum, but it was partially evacuated and this contributed some to cutting down the transmission of sound.

Mr. FULTON. Is there any work being done in the vacuum field on reducing noise? That was the question.

Dr. BOLT. Yes, it has been applied in this particular case. I am not sure that studies of vacuum, as such, would be very much more fruitful at this stage.

Mr. FULTON. Thank you, Mr. Chairman. That is all.

The CHAIRMAN. You are introducing two other witnesses?

Dr. BOLT. If I may.

The CHAIRMAN. Mr. L. N. Miller, senior engineering consultant, Bolt Beranek & Newman, Inc., Cambridge, Mass., and the other is Dr. Kryter.

Dr. BOLT. I should like first to introduce Dr. Kryter, who will say a few more words about how we measure the responses of people.

The CHAIRMAN. You can keep your seat, Dr. Bolt.

Dr. BOLT. Very well, sir.

STATEMENT OF DR. KARL D. KRYTER,[3] SUPERVISORY ENGINEERING PSYCHOLOGIST, BOLT BERANEK & NEWMAN, INC.

Dr. KRYTER. Mr. Chairman and gentlemen. I, too, would like to express, if I may, regrets in behalf of Dr. Beranek for his being physically unable to be here. I know he worked very hard on his testimony. At the same time, I appreciate the opportunity to appear, and I am happy to do so.

The CHAIRMAN. May I say parenthetically that we deeply regret that the doctor is not able to be here this morning. However, I want to say for the record, that he sent two very capable men to represent him here. We are happy to have them.

Dr. BOLT. Thank you.

Dr. KRYTER. Thank you.

The CHAIRMAN. We hope his recovery is quick and permanent.

Dr. KRYTER. Thank you, sir.

Rather than read part of Dr. Beranek's testimony I would like to discuss with you certain human factors problems in external noise from aircraft. Let me outline briefly what I think these problems are

[3] Karl D. Kryter: Dr. Kryter is a supervisory engineering psychologist with Bolt Beranek & Newman, Inc. He received the Bachelor of Arts degree in psychology in 1939 from Butler University and the Doctor of Philosophy degree in psychology in 1943 from the University of Rochester. Dr. Kryter was Research and Teaching Assistant at the University of Rochester, 1939–1942; Research Fellow, Psycho-Acoustic Laboratory, Harvard University, 1942–1945; Research and Teaching Fellow and member of the Systems Research Laboratory, Harvard University, 1945–1946; Assistant Professor of Psychology, Washington University, 1946–1948; and Director of the Operational Applications Laboratory, Air Force Cambridge Research Center, Air Research and Development Command, 1948–1957. The Operational Applications Laboratory was formerly titled Human Resources Research Laboratories (1948–1952) and, Human Factors Operations Research Laboratory (1952–1954). At the Harvard Psycho-Acoustic Laboratory, Dr. Kryter conducted studies aimed at improving speech communication in noise and at high altitude. At the Systems Research Laboratory, he worked on the organization of Naval Combat Information Centers, the human engineering evaluation of equipment and on training methods and exercises to improve the performance of shipborne radar and fire-control systems. He organized in 1948, and then supervised the Air Force's Human Resources Research Laboratories. The program of that organization (and under its subsequent titles) was concerned with: basic research on human information processing and speech communication and applied research on personnel training and the evaluation of human and systems performance under operational conditions. Dr. Kryter is a Fellow in the American Psychological Association, the Acoustical Society of

and where, with respect to research and application, we stand in these human factors areas.

There appears to me to be three broad aspects or parts to these human factors problems. Part 1 is that of measuring the inherent response of the average human being to different kinds of sounds.

America, and the American Association for the Advancement of Science; he holds membership in the Human Factors Society of America and the American Statistical Association and Society of Sigma Xi.

Papers by Karl D. Kryter:

[OSRD is Office of Scientific Research and Development. Papers with "PB" numbers are available from the Office of Technical Services, U.S. Department of Commerce, Washington, D.C.]

"Frequency-Localization in the Auditory Cortex of the Monkey," J. C. R. Licklider and K. D. Kryter Pred. Proc. Am. Soc. Exp. Biol. 1, 51 (1942) [A].

"Studies on the Function of the Higher Acoustic Nervous Centers in the Cat," K. D. Kryter and H. W. Aides, Am. J. Psychol. 56, 501–536 (1943).

"Articulation-Test Comparisons of Six Signal Corps Aircraft Interphones at Low and High Altitudes," K. D. Kryter and D. A. Ross, OSRD 1947, PB 22909 (1944).

"Articulation Tests of Standard and Modified Interphones, Conducted During Flight at 5,000 and 35,000 Feet," J. C. R. Licklider and K. D. Kryter, OSRD 1976, PB 5505 (1944).

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By this, we mean man's response to sounds independently of the meaning those sounds may have for him.

In short, we wish to convert the decibels that Dr. Abbott spoke of into units that have meaning or tell us how people respond to sounds, rather than how the meter that reads in decibels responds to these sounds.

Part 2 of this general problem is to measure the feelings people have about aircraft noise because the noise bothers them or disturbs them.

This, of course, is a more complicated part of the problem than the first part.

Part 3 I think is the establishment of criteria of tolerability of acceptability; that is to say, how much, how often, and when people can justifiably be exposed to intense aircraft noise.

These are all fairly complex problems, but there are data and experience available on all three parts of this question.

Let me try to give some more detail on each. First, the measurement problem. I think a fundamental building block is needed to evaluate aircraft noise or any type of noise. We need a unit or a scale that tells us how people value or evaluate the loudness or the intensity or the noisiness of a sound.

At the same time I wish to make clear that this evaluation unit should be independent of, let's say, how frightful the sound is, how one person might feel toward it because of some experience he has had with it, because of its novelty, or the like.

We have available at the present time a scale that is coming into fairly wide use now that will convert the decibel sound pressure measurements made by engineers into so-called perceived noise level—the unit in this scale is the PNdb.

Let me tell you in a few words how this scale was derived.

About 15 years ago a number of people were asked to judge at the Harvard Psycho-Acoustic Laboratory the relative loudness and noisiness or annoyance value of different kinds of artificial, meaningless sounds.

From this, a method was derived in which we could convert the physical decibel measures made upon many types of sound into this scale of perceived noise levels.

An important point to make here is that in the past year something like 200 people have been studied at Bolt Beranek & Newman, Inc., with respect to how they feel about aircraft sounds, both jet and piston. In England, recently, 1,600 people were also used in a long experiment on this subject. And elsewhere studies have been done. In general, these studies have validated the perceived noise level as the most appropriate method available at this time for measuring the effects of noise upon people.

Now, again, the PNdb scale is a measure of the effect of noise without regard to emotional feelings; it measures how the ear and the brain as an auditory system respond to sound. We are trying to measure the way the human organism as a filter and a meter reacts to sound, independently of any meaning the sound may have to the listener.

I think this PNdb unit has two important features. First, it appears to have validity. Let me point out that the decibel scale of the standard method for expressing the intensity of sound does not

have validity for measuring human response and is very misleading in the aircraft noise situation.

For example, if you present the noise of a piston aircraft to a person that reads, let's say, 100 decibels, and have him listen to it and say how loud he thinks it is, and then you present to him the sound from a jet aircraft, the same flight conditions, also at 100 decibels, and ask him how loud he thinks that is, you will find that the average person will say that the piston aircraft is about one-half as noisy as the jet. Converted to the decibel scale this means that a 10-decibel handicap is carried by the jet noise because of the way people react to it. I might add parenthetically here that Lily Pons and other singers quite often hit 100 decibels. Perhaps this gives you a concept of how meaningless the decibel unit is, in its raw form, for expressing how the ear responds to sound.

The second thing, and perhaps the most important, is that this unit gives us a building block with which we can intercompare, in a fairly meaningful way, the noise environments that people have been exposed to in the past, that they are now being exposed to, and that they will be exposed to in the future as now estimated.

This has been done, for example, for the communities near Idlewild Airport in New York, where calculations have been made to show what the perceived noise levels will be for future jet operations, relative to what it has been for piston operations.

Let me say most emphatically, however, that this unit is only a starting point for understanding the noise environment of a community. The PNdb is not a specific criterion. You cannot say, for example, that 100 PNdb, or 112 PNdb, is a level that is tolerable. You can say, however, that a piston engine aircraft at 112 PNdb sounds as noisy as a jet at 112 PNdb.

If we are to evaluate a community's feelings about these sounds, we must take into account also how many flights there are a day, what time of day they occur, and the like.

I also do not wish to imply that the perceived noise level unit does not require further research and development. It does. For example, we know from recent experiments on the effects of the sounds similar to that of the new turbofan engine for aircraft that the PNdb unit as presently calculated, underestimates by 8 or 10 PNdb the judged noisiness of the turbofan engine.

We must add here, of course, that because of the greater thrust and different flight conditions, the noise on the ground may be less for an aircraft in flight with turbofan engines than with present jet engines; but nevertheless, the point here is that these new noises have characteristics that the perceived noise level and, of course, the decibel scale, do not properly evaluate.

Finally, let me hastily say that the question of criteria, or how to specify what is an acceptable noise environment, is a most complex one. To establish criteria for a particular situation one must take into account the whole system, the whole community's environment, and many things must be specified in addition to PNdb values.

Perhaps we could give an analogy here with respect to the criteria problem, and that is this: in the past the railroads, as we all know, have made noise, and this has become, in the past—perhaps it is mostly forgotten now—a problem much like the one we have here.

As I understand it, there have been court judgments that these railroad sounds were, at high levels, a compensable nuisance. We

made some recent calculations which indicated, at least for certain trains, that one would have to be within about 3 feet from the train to have a perceived noise level that was comparable to the levels experienced under a modern jet several miles from the start of takeoff roll. In other words, the modern jet aircraft, and to a greater extent those planned for the near future, can create noise conditions under their flight paths that are several orders of magnitude more severe than those experienced in the average home near railroads in the past.

Thank you. Those are the comments that I wish to make.

The CHAIRMAN. Thank you very much, Doctor.

At this point, and I am sure there is no objection, we will introduce for the record the testimony of Dr. Beranek, who is absent today because of illness.

PREPARED TESTIMONY OF DR. LEO L. BERANEK,[4] PRESIDENT, BOLT BERANEK & NEWMAN, INC.

I. AFFILIATION

I am president of a research and consulting firm, Bolt Beranek & Newman, Inc., 50 Moulton Street, Cambridge, Mass., and I am a lecturer at the Massachusetts Institute of Technology.

Bolt Beranek & Newman, Inc., founded in 1948, is dedicated to providing an advanced level of applied research and consultation, in a variety of fields, for Government and industry. Bolt Beranek & Newman, Inc., has no manufacturing facilities.

In the field of aircraft noise, the interests of Bolt Beranek & Newman, Inc., include research and development for the control of noise from jet and propeller aircraft in flight, from jet and reciprocating engines during ground runups, and from missiles and rockets during takeoff.

BBN has also designed noise control for major subsonic and supersonic wind tunnels for aircraft research in this country and is currently engaged in research on the effects of high-intensity noise on fatigue of aircraft and missile structures.

In addition, BBN has been active in studying the reactions of people to noise produced in communities by aircraft operations on or from nearby airports.

Bolt Beranek & Newman, Inc., has performed engineering services related to aircraft noise, its control, and the reaction of people to it, for the majority of large engine and airframe manufacturers, for the Air Force, the Navy, the Army, the NACA, and for major airports in the United States and Western Germany. These organizations have over a period of years placed contracts with BBN for a total of about $3 million for work on aviation noise problems.

[4] Dr. Leo L. Beranek is president of Bolt Beranek & Newman, Inc., Cambridge, Mass., a research and consulting organization in the fields of physical and engineering acoustics, architectural acoustics, engineering psychology, and biophysical instrumentation. He is also a lecturer on acoustics at the Massachusetts Institute of Technology.

Dr. Beranek received the degree of bachelor of arts "with distinction" from Cornell College, Iowa, in 1936, the degrees of master of science and doctor of science from Harvard University in 1937 and 1940, respectively, and an honorary degree of doctor of science from Cornell College in 1946.

From 1941 to 1943, he was assistant professor of physics and communication engineering at Harvard. From 1943 to 1946, he was director of Harvard's Wartime Electro-Acoustic and Systems Research Laboratories, supported under funds of the Office of Scientific Research and Development of the Office of the President. He was technical director of the acoustics laboratory at MIT from 1947 to 1954 and associate professor of acoustics from 1947 to 1959.

Dr. Beranek has won wide recognition as an authority on acoustics. He has published between 60 and 70 technical papers and articles and has authored the following books: "Sound Control in Airplanes" (1944), "Acoustic Measurements" (1949), "Acoustics" (1954), and "Noise Reduction" (1960).

In 1948 Dr. Beranek received a Presidential citation from President Harry S. Truman for scientific contribution to World War II. In 1944 the Acoustical Society of America awarded him their biennial award for outstanding contribution to acoustics.

Dr. Beranek is a fellow of the American Academy of Arts and Sciences, the American Physical Society, the Acoustical Society of America, the Institute of Radio Engineers, the Audio Engineering Society, and the American Association for the Advancement of Science. He is a member of Sigma Xi, Eta Kappa Nu, and the New York Academy of Sciences. Dr. Beranek is a past president of the Acoustical Society of America. He is at present chairman of the Acoustical Standards Board of the American Standards Association.

Dr. Beranek presented the 45th Thomas Hawksley Lecture before the Institution of Mechanical Engineers in London in November 1958. He has also lectured on acoustics before the Physical Society of London, the Zurich Federal Institute of Technology, the Swiss Society of Architects and Engineers, the Technical University of Prague, the Polish Academy of Sciences in Warsaw, the Acoustical Institute of Moscow, the University of Moscow, the Engineering Society of Finland, and the University of Buenos Aires.

II. PUBLICATIONS OF BBN IN THE FIELD OF AIRCRAFT NOISE

A partial list of scientific reports and papers that have been published in the field of aircraft noise by BBN cover the following subjects:

1. Noise from jet engines. (See app. A.)
2. Control of noise arising from ground runups of engines. (See app. B.)
3. Noise in communities around airports and the reaction of people thereto. (See app. C.)
4. Noise and vibration of missiles and rockets. (See app. D.)

III. ITEMS OF PROBABLE INTEREST TO THE HOUSE COMMITTEE ON SCIENCE AND ASTRONAUTICS

A. Jet engine noise and noise reduction

Noise from a standard jet engine originates from two principal sources, the intake compressor and the exhaust blast. Intake compressor noise, assuming a standard jet engine, can usually be heard during the approach for landing and while the airplane is taxiing on the ground. It is seldom heard on takeoff. The noise that is heard during takeoff (again speaking of a standard jet engine) does not originate inside the engine. It is produced outside the engine by the ejected high-speed hot gas which rushes into the still surrounding air. This escaping gas, which provides the propulsion thrust, causes turbulence at the interface between the still air and the fast-moving air and this turbulence, in turn produces an intense roaring noise. This noise is crudely analogous to that heard when a large stick is pulled rapidly through a body of water.

Present-day noise-reduction devices added to an existing jet engine reduce this external noise by modifying the manner in which the high-speed jet-exhaust stream is mixed with the still air.

However, reduction of the exhaust turbulence noise on an existing engine by these devices is usually associated with some loss of performance.

The answer to the problem of achieving large reductions in exhaust noise while maintaining performance is in designing jet engines from their inception so as to achieve the desired thrust with minimum exhaust interface turbulence. These designs must have a low-exhaust velocity and, therefore, are characterized by a larger mass flow of gas and a larger exhaust open area than is the case for standard jet engines. Such a design will produce the desired thrust with a lesser amount of exhaust interface turbulence.

In the turbofan type of jet engine (about to be introduced into air transport service) a lower exhaust velocity is achieved. For an equivalent thrust, the noise arising from air turbulence is therefore less. Unfortunately, the added internal turbofan itself produces an intense shrill tone. This shrill tone can be reduced by proper mufflers placed on the intake and exhaust of the jet engine. Such mufflers have been successfully demonstrated by engine manufacturers. These mufflers, although effective acoustically, do add weight and drag, thus decreasing the overall performance of the engine.

Just as in the case of the standard jet, noise reduction can be achieved only through some sacrifice in aircraft performance. It must also be remembered that there is a minimum practical level to which the shrill-tone noise of a turbofan engine need be reduced by mufflers. This level is reached when the shrill tone has been reduced so far that the remaining noise is due to the turbulence of the air behind the exhaust.

It must also be noted that no advantage to the people living under a flight path will be achieved as a result of the introduction of the turbofan engine in place of the standard jet engine, if this new engine is operated at higher thrust (than the conventional engine) and if this extra thrust is used to carry a greater payload. A turbofan engine with increased thrust may be as noisy as a standard engine with lower thrust.

Therefore, if a turbofan engine with increased thrust passes over a neighborhood at the same altitude as a standard engine, the noise levels under the flight path will be the same. The result of the introduction of the turbofan engine then could be only an increase in payload and not a decrease in noise.

One of the most serious obstacles to the achievement of noise reduction in a community has been the continual increase in the thrust of engines which counterbalances the possible decrease in noise achieved by new principles of design.

To the best of my knowledge, no engine has yet been designed in this country with the starting premise that the lowest possible noise level for a given thrust should be achieved. The cost of developing a new engine that deviates drastically from those designed for military aircraft is said to be so high that commercial air carriers cannot alone afford to underwrite it.

Whether the "ultra-quiet" engine would take a form that has an exhaust slot extending for 20 feet along the rear edge of a wing, or whether it would simply have a very large diameter remains to be seen.

There seems to be no practical alternative to the achievement of quieter engines. Airport neighbors must live in noise environments that are tolerable even though air traffic and thrust requirements continue to increase. It is as simple as that.

B. What is the PNdb method of rating aircraft noise?

The inadequacy of the common or garden decibel as a means of rating "noisiness" judged by people has long been recognized. The Acoustical Society of America, which helps prepare standards for noise, has never claimed that the decibel was anything other than a physical measure of the intensity of a sound wave, using a sound level meter as the measuring instrument.

In order to indicate "noisiness," the meter reading in decibels (db) must be converted into a form that is related to the reaction of human beings to the noise being measured.

Originating from fundamental information already in the scientific literature and subsequently fully validated for present-day engine noise by several thousand listeners in the United States and England, the perceived noise level measured in perceived noise decibels (PNdb) has come into widespread use. The perceived noise level has the following meaning:

It expresses in a compact manner (PNdb) the measure of "noisiness" that is implicit in listeners' reactions to sound.

2. It is formulated in such a way that conversion from ordinary decibels to perceived noise decibels is readily accomplished. The PNdb scale is similar in structure to the more familiar common decibel scale.

The word "perceived" in perceived noise level indicates that the sound is heard and measured in the listener's mind. Noise is defined, as in the standard acoustical terminology of the American Standards Association, as "unwanted sound." "Level" implies, as it usually does in technical work on acoustics, that the scale is logarithmic and that the units are decibels.

The perceived noise level (in PNdb) is a means of rating the inherent "noisiness" of a sound without regard to the different meanings that sound may have to different people. There is nothing inherent in the definition of the perceived noise level that says that 110 PNdb or 120 PNdb or some other number of PNdb will or will not be acceptable to people living near airports. The acceptability of aircraft noise to a neighborhood depends upon at least the following factors:

(*a*) The perceived noise level (how many PNdb).

(*b*) The time of day. For example, a neighborhood accepts more noise in the daytime than at night due to various reasons.

(*c*) The presence of other noises. For example, noise from highways, railroad trains, factory operations, and so forth.

(*d*) The attitude of the community toward the airport.

(*e*) The number of aircraft that take off or land during any one day.

(*f*) Season of the year.

The final policy decision on the exact number of perceived noise decibels to specify as a maximum for aircraft operations over neighborhoods must ultimately be the decision of the airport operator. To its airport clients, Bolt Beranek & Newman, Inc., has always pointed out the nature of community attitudes, as we have witnessed them, that exist around various airports and air bases as a result of air operations there.

To correlate with these observations, we have measured the noise levels on a statistical basis from aircraft operations around those same airports and air bases. These measured noise levels, along with items (*b*) through (*f*) above, and the observed neighborhood reactions are reported to the airport involved.

Based upon this information and upon other experience at their own and at other airports, some airport authorities have specified upper limits to the noise from jet aircraft on takeoff that they will permit in neighborhoods around their airports.

The maximum permissible number of perceived noise decibels is expected to vary from one airport to another, depending upon items (*b*) through (*f*) above. For example, the Port of New York Authority has specified a maximum perceived noise level of 112 PNdb in neighborhoods surrounding the New York International Airport, to which operators of jet aircraft are required to adhere on takeoff between 7 a.m. and 10 p.m.

No takeoffs of jet aircraft over communities are permitted between 10 p.m. and 7 a.m. On the other hand, the Ministry of Aviation of England has, on June 1, 1960, introduced a limitation of 110 PNdb measured in the main built-up areas

under the takeoff paths at London Airport, to which operators of jet aircraft are required to adhere by day.

C. Research at BBN on the effects of noise on people

Under contract support provided by the U.S Air Force, the Port of New York Authority and the National Institutes of Health and others, our firm has been studying and developing methods of evaluating the psychological or subjective reactions that people evince to various sounds and noises (including jet aircraft) as function of their intensity, duration, tonal content, and so forth. We are also doing some exploratory research on the effects of sounds, including that from jet aircraft, upon sleep.

In addition, a study is being conducted on the effects of intense low frequency sounds such as may be present in or near missiles upon hearing and speech communication.

We believe that much more effort should be expended in these areas of investigation. Our studies so far have included only the present-day types of jet noises. Almost nothing has been done on missile or turbofan jet noises.

Detailed observations of community response to aircraft noise have been made to date around a limited number of airbases and airports with a view to developing operational procedures that would be equivalent to substantial noise reduction.

In other words, to do a complete scientific job on the application of the perceived noise decibel concept to future developments, we need to do more research.

At this moment, contracts with our firm on this subject amount to only a token effort in spite of the fact that we probably have the most experience and a very great interest in doing continuing work.

I view the need for research on the human factors problems involved in airport operations as most serious to the future of commercial aviation. (More is said on this subject in sec. H of this testimony.)

D. Proposed FAA regulations regarding current jet operations at New York International Airport

The Federal Aviation Agency (FAA) has recently published draft release No. 60–10, regulations docket No. 380, "Notice of Proposed Rulemaking—New York International Airport Traffic Pattern Area Rules."

They have solicited comments from all interested parties. This proposed regulation undertakes to set up a special civil air regulation intended to reduce the noise of flight operations of all aircraft operating on and in the vicinity of New York International Airport.

We can readily show that the FAA proposes to adopt noise reduction rules that will, on the average, result in higher noise levels in the communities than are allowed by the rules now in force by the Port of New York Authority.

Based on our intimate understanding of the aircraft noise exposure in the residential communities near New York International Airport, we believe that the position of the PNYA is consistent with the scientific and technical evidence before us today. Our detailed comments are as follows:

We believe that this move of the Federal Government to establish air traffic regulations with the force of law bodes well for residents around airports at all of our cities.

Jet operations are increasing in number at our major airports. Smaller airports will soon be receiving scheduled jet flights. It appears to be extraordinarily difficult for airports, major and small, to extend their boundaries or to displace people around them.

Hence, air traffic regulations designed to limit the noise produced in neighborhoods are mandatory until technological developments should produce quieter airplanes.

The proposed FAA rules fall short of their stated goal. Aside from establishing a preferential runway system, which is, of course, essential as a first step, the rules for takeoff simply say—

"* * * all fixed-wing aircraft climb to 1,500 feet as rapidly as practicable * * * an exception is provided in the rule for certain aircraft which are capable of producing less noise in a slower climb rate * * *."

In our opinion, a successful program of noise control for a community must place actual limits (in PNdb) on the noise produced by aircraft as they pass overhead.

It is easily demonstrable that simple compliance with the FAA rules will permit noise levels far in excess of those reasonable in the neighborhoods around New York International Airport.

The proposed rules state that they are designed to reduce noise "* * * to the extent consistent with safety." They apply only to the manner in which aircraft are to be operated under existing conditions of wind, weather, available runway length and aircraft weight.

They fail to recognize that one of the most important of the conditions governing aircraft noise levels, the weight of the aircraft, is a condition which is under the control of the aircraft operator.

The aircraft dispatchers should be required to take the preferential runway rules, the distance to the nearest community and the maximum permissible noise levels into account when computing the maximum permissible takeoff weight for any particular flight.

For any given flight the weight of the airplane is determined by the number of passengers, the amount of fuel required for the trip, and the amount of cargo carried.

For only a portion of the flights are all three of these items at a maximum. In these few instances, to meet a required PNdb level, the plane might have to depart with less than full load.

While such planning involves economic considerations, it in no way affects flight safety and we can see no reason why it cannot be done. The FAA, the airports, the airline operators, and the aircraft manufacturers are today expected by the people to appreciate that high-speed travel entails some serious down-to-earth noise problems. The loss of possible revenue in the interests of noise control must simply be accepted as one of the costs of operating a modern transportation system.

In addition, we note that the proposed rules fail to recognize that noise during certain hours of the night is more disturbing to the residents of a community than noise during the day.

The FAA should provide more stringent regulation of scheduled nighttime takeoffs over communities than daytime takeoffs. The regulations of the British Ministry of Aviation and the Port of New York Authority at present provide for no jet takeoffs over communities at night.

We heartily endorse the proposed FAA rule that, "When approaching to land on a runway served by an instrument landing system, large fixed-wing aircraft shall remain at or above the glide slope altitude between the outer marker and the middle marker."

In addition, pilots should be required to land jet aircraft with as low an engine thrust as possible, consistent with safety. Also, it seems to us that as high an angle of descent as possible should be specified for runways that do not have instrument landing systems.

An important item of development that should be seriously considered is means for landing heavy aircraft at a steeper angle of approach with low engine thrust. Altitude and low thrust are aviation's most effective means of community noise control.

By different airplane design, more effective use could be made of preferential runways. Landings and takeoffs would be possible on these runways with higher cross-wind components if the aircraft were equipped with cross-wind landing gear. This type of landing gear appears to have proven feasible on the B–52 bomber. Development effort in this direction is indicated.

E. Noise due to future commercial supersonic aircraft

Bolt Beranek & Newman, Inc., is currently studying the outlook for future aircraft developments as they may influence noise in residential areas near airports. We observe the possibility that commercial supersonic transports may come into use in the next 15 or so years. This again emphasizes the urgent need for noise reduction research so that these planes may be able to operate without creating intolerable noise in communities near airports.

For example, based on present-day estimates of the noise of future turbofan jet engines in the thrust range of 30,000 to 40,000 pounds it appears that the noise output of these future engines at the source would be approximately 6 to 10 PNdb greater than the noise output of the 12,000- to 15,000-pound thrust jet engines that power our present-day commercial jet aircraft. In addition, one school of thought supposes that the larger supersonic tranpsorts of the next two or three decades would be powered by six or even eight of these high thrust engines. This larger number of engines adds 2 or 3 PNdb additional noise output at the source (relative to an aircraft with four engines). This indicates once more that something must be accomplished in the foreseeable future to insure that aircraft will not produce about 8 to 13 PNdb greater noise at the source than current aircraft. This estimate assumes a reasonable amount of engineering

progress in the reduction of engine noise during the time involved in developing the new aircraft, but it does not presume any major, fundamental changes in propulsion systems that might alter the noise problem drastically. It is obvious that accelerated research effort on engine design in the next decade is needed to prove this estimate to be incorrect.

If, however, supersonic aircraft cannot be held to a lower decibel level than is now estimated, the aircraft will have to be able to climb at steeper angles on takeoffs and descend at steeper angles on landings to protect airport neighbors from excessive noise. We wonder whether the passengers in the aircraft will accept the very steep takeoff and landing angles required.

While it would appear that this amount of noise excess could be overcome by substantial enlargement of airport boundaries, most airports cannot expand their boundaries. Research must find a solution in aircraft design.

To summarize, amongst other facets of the future noise problem, the overall picture suggests need for research in jet engine noise reduction, research in presently unknown or little-known methods of propulsion that might be applicable to aircraft movement, development of aircraft with steeper landing and takeoff profiles, an appreciation by aircraft manufacturers and airline operators that the noise associated with high speed travel could be very serious even to the point of grounding intolerable aircraft. In addition, there must be an effective sympathetic program of technical and economic assistance to airport managements and airport residents to make airports compatible with their neighbors.

F. The sonic "boom"

Associated with a supersonically traveling airplane is a pressure wave which is heard as a "boom" when it reaches the ears of a listener. Of course, this boom is stronger as one gets closer to the aircraft producing it. But this boom is more serious than the sound it makes. It has been observed that window breakage in buildings can occur when the distance from aircraft to ground is less than 30,000 feet when the aircraft is traveling at a supersonic speed. Striking case histories of the damage that can result have occurred at the Ottawa airport terminal and in Oklahoma City. An accidental severe sonic boom over a large city might have severe consequences.

The FAA should today set mandatory rules for the operation of all present military and future commercial supersonic aircraft to avoid positively any operations near major cities that would result in even moderate sonic booms. The FAA must establish suitable city-avoiding transcontinental and intercontinental flight paths in order to make it possible for commercial supersonic travel to become a reality.

To avoid any misunderstanding I wish to emphasize that during the subsonic portions of the takeoff and landing operation there is no problem of sonic boom, and during very high altitude flight (about 30,000 feet) at supersonic speed sonic booms are audible, but usually not damaging.

Close attention also should be paid to the minimum safe distance between two airplanes in flight when at least one of them is traveling supersonically. Such studies may have important implications in the selection of airways for supersonic aircraft and in the design of aircraft structures to withstand such a sonic encounter.

To cope with the problem of the sonic boom research should be encouraged on the control of minimizing of such booms.

G. Noise-induced fatigue of materials in supersonic aircraft

The structural fatigue of subsonic aircraft induced by the noise of its jet engines has already been recognized as the cause of severe maintenance problems. Supersonic aircraft of the future will greatly increase this problem.

In present-day subsonic turbojet aircraft the most severe fatigue exposure occurs during ground and low-speed operation of the aircraft at high power settings of the engines. The supersonic airplane will exhibit the same difficulty but to an even greater extent. Again, the need for noise reduction research is apparent when one realizes that, without improved noise control, the noise of an engine powering a supersonic airplane would be 6 to 10 db greater than the noise of present-day turbojets. Expressed differently, the fatiguing forces on aircraft structures will increase by factors of 2 to 3. This increase would result in an exceedingly large reduction in the operating life of structures that are undergoing fatigue. For example, certain structures in the vicinity of the engines on today's subsonic jet airplanes are expected to need replacement after a total operating life of about 2 years. With 6 to 10 db noisier engines the same structures would need replacement within 2 to 80 hours. Inasmuch as many structures on

today's commercial and military subsonic aircraft need replacement after about 2 years of operating time, we may expect that supersonic aircraft will exhibit exceedingly costly maintenance problems unless there is further noise reduction.

Military and commercial aviation interests have recognized the problem of noise-induced fatigue and are currently pursuing research and development programs to combat the problem. This important effort must be expanded and must be brought to fruition at about the time that supersonic transports are destined for operation. It is clear that should the research effort in noise-induced fatigue lag we will have a fleet of supersonic transports that spends much more time in maintenance shops than in the air.

In addition to the noise generated by the powerplants, a supersonic airplane in flight is subjected to a noise field due to the turbulent layer of air immediately surrounding it. This boundary layer turbulence would be the most important contribution to noise within the airplane during supersonic travel and thus is an important noise problem of commercial supersonic flight requiring further research.

H. Noise problems associated with large rockets and missiles

The high-power rocket engines of contemporary and future space vehicle designs pose some new noise problems. Along with the higher jetstream power of these engines there is a corresponding increase in the sound radiated. Some of the engines contemplated for the near future will have as much as 20 db greater sound radiation than the most powerful turbojet engines in operation today. Furthermore, the rocket engines tend to radiate large amounts of noise in the subaudible range (below about 20 cycles per second). Noise in this range of frequencies will give rise to new reactions by human beings and to greater potential damage to building structures.

Almost no attention has been paid to the possibility of achieving noise reduction of rocket engines. Although some information is already available for achieving a limited amount of noise reduction by natural techniques (i.e., techniques whose primary function is something other than noise control, such as jetstream deflectors and water spray addition) almost no test sites are being designed today with this information in mind.

Information on the amount of noise reduction afforded by these natural devices is needed, and, when determined, it should be communicated to site designers so that they can make maximum use of what is in essence "free" noise reduction. Furthermore, almost no attention has been paid to the possible application of diffusing techniques such as those now used for noise control on turbojet engines. While the amount of noise reduction to be expected from such devices is not large, we should not overlook this important possibility. Finally, no attention seems to have been given to the possible design of acoustically closed test cells for static testing of rocket engines. Today such tests are always carried out in the open or at best in a hardened excavation. We know that the development of the turbojet engine was greatly facilitated by the availability of noise-reducing engine test cells. No comparable development appears to be underway for the testing of rocket engines.

There appear to be three problems associated with rocket noise that deserve immediate attention and concentrated research effort: (1) the establishment of rational criteria for noise from rocket engines, (2) the study of outdoor propagation of rocket noise, particularly over very long distances, (3) the development of noise control methods, which we have already discussed above.

The task of selecting a rational criterion for noise in communities surrounding a rocket engine test or launching site is not an easy one. Although many such military sites are now operative, there are little direct data bearing on the problem of community response to the noise. We need community noise and reaction surveys such as were carried out starting about 10 years ago when jet aircraft operations began to be important. Without such surveys, it does not appear possible to proceed with a rational evaluation of the overall problem. In addition to the reaction of humans in such surveys we must also study possible building damage, particularly at locations very near (less than 1 mile) the test area.

Because of the large amount of low-frequency energy radiated by rocket engines, we need to study the problem of propagation of long-range low-frequency sound through the atmosphere. In the past 10 years significant strides have been made in understanding the propagation of high-frequency sound (e.g., sound from present-day aircraft) through the atmosphere above the ground, mainly because of the interest in turbojet aircraft noise. The studies have heretofore been confined to noises propagated over distances of only a few miles. In the case of rocket engine noise we need information on long-range propagation (up to at

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least 10 miles) for low-frequency noises in the range of about 1 to 100 cycles per second. Because of the longer distances and the lower frequencies, high-altitude atmospheric effects play an important role in the propagation. It is often observed that noise from test sites can be focused by the atmosphere and at great distances noise levels will occur that are comparable to the levels adjacent to the test site. We need to develop improved upper-air meteorological techniques for use in conjunction with rocket tests to predict and thus avoid the occurrence of such focusing phenomena.

I. Noise radiated externally by helicopters

Airports serving many of our cities are located considerable distances from the business centers. Helicopters are coming into greater use as a means of covering these distances rapidly. But the expansion of in-city helicopter services has been greatly hindered by the external noise radiated from the engines and the rotors. In fact, many cities have had bans, due to noise, in effect against helicopters for many years.

The helicopters currently flying in this country were designed to serve military and air-rescue needs. Little attention was paid to the external noise radiated by them. Noise control for helicopters is feasible, but it must be planned for in design and must be engineered and flight tested by the manufacturers. Retro-fit kits are seldom very effective.

On the assumption that extensive use of helicopters for in-city operations is of national interest, research and development contracts should be let for (*a*) means for lightweight noise control on helicopter propulsion systems, (*b*) rotor blade design for minimum noise, and (*c*) development, manufacture and testing of helicopters that have as one of their basic design tenets, low external noise.

(Appendixes A through D, inclusive, are as follows:)

Appendix A. Reports and Papers on Jet Noise

1. Mawardi, O. K. and I. Dyer. "On Noise of Aerodynamic Origin." Journal of the Acoustical Society of America 25: 389–395, May 1953.

2. BBN Report No. 329: The Effect of Teeth on the Noise From a Jet Engine Agency: USAF. Date: July 1954.

3. BBN Report No. 340: The Influence of Engine Design Parameters and Atmospheric Conditions on the Acoustic Power Output of Turbojet Engines. Agency: USAF. Date: 24 January 1956.

4. BBN Report 341: A Compilation of Turbojet Noise Data. Agency: USAF. Date: 25 July 1956.

5. Franken, Peter A. "Review of Information on Jet Noise." Noise Control 4: 8–16, May 1958.

6. Dyer, I., P. A. Franken and P. J. Westervelt. "Jet Noise Reduction by Induced Flow." Journal of the Acoustical Society of America, 30: 761–764, August 1958.

7. Dyer, I. "Distribution of Sound Sources in a Jet Stream." Journal of the Acoustical Society of America 31: 1016–1022, July 1959.

Appendix B. Control of Jet Ground Run-Up Noise

1. Bolt, R. H. "The Aircraft Noise Problem." Journal of the Acoustical Society of America 25: 363–366, May 1953.

2. Beranek, L. L., S. Labate and U. Ingard. "Noise Control for NACA Supersonic Wind Tunnel." Journal of the Acoustical Society of America, 27: 85–98, January 1955.

3. Watters, B. G., S. Labate, and L.L. Beranek. "Acoustical Behavior of Some Engine Test Cell Structures." Journal of the Acoustical Society of America, 27: 449–456, May 1955.

4. Dyer, Ira. "Noise Attenuation of Dissipative Mufflers." Noise Control 2: 50–57, 78–79, May 1956.

5. BBN Report No. 343: Noise Produced by Aircraft During Ground Run-Up Operations. Agency: USAF. Date: February 1957.

6. BBN Report No. 511: Guide for the Analysis and Solution of Air Base Noise Problems. Agency: USAF. Date: December 1957.

7. BBN Report No. 529: Noise Control for Aircraft Engine Test Cells and Ground Run-Up Suppressors, Vol. I—Measurement and Analysis of Acoustical Performance. Agency: USAF. Date: February 1958.

8. Pietrasanta, A. C., and K. N. Stevens "Noise Exposure in Communities Near Jet Air Bases." Noise Control 4: 29–36, 75, March 1958.

9. Pietrasanta, Adone C. "Aircraft Noise and Building Design." Noise Control 3: 11–18, 88, March 1957.
10. BBN Report No. 548: Noise Control for Aircraft Engine Test Cells and Ground Run-Up Suppressors, Vol. II—Design and Planning for Noise Control. Agency: USAF. Date: December 1958.

APPENDIX C. AIRPORT NOISE AND HUMAN REACTION THERETO

1. Beranek, L. L. "Unsolved Military Noise Problems." Journal of the Acoustical Society of America 24: 769–772, November 1952.
2. BBN Report No. 351: Office Noise Studies at Hill AFB. Agency: USAF. Date: August 1956.
3. Beranek, L. L. "Revised Criteria for Noise in Buildings." Noise control 3: 19–27, January 1957.
4. BBN Report No. 342: Noise Produced on the Ground by Jet Aircraft in Flight. Agency: USAF. Date: 15 February 1957.
5. Miller, L. N., and L. L. Beranek. "Comparison of the Take-Off Noise Characteristics of the Caravelle Jet Airliner and of Conventional Propeller-Driven Airliners." Journal of the Acoustical Society of America 29: 1169–1179, November 1957.
6. BBN Report No. 606: Studies of Noise Characteristics of the Boeing 707–120 Jet Airliner and of Large Conventional Propeller-Driven Airliners. Agency: PNYA. Date: October 1958.
7. BBN Report No. 607: Studies of Noise Characteristics of the Comet 4 Jet Airliner and of Large Conventional Propeller-Driven Airliners. Agency: PNYA. Date: October 1958.
8. Miller, Laymon N., Leo L. Beranek, and Karl D. Kryter. "Airports and Jet Noise." Noise Control 5: 24–31, January 1959.
9. Beranek, Leo L., K. D. Kryter and Laymon N. Miller. "Reaction of People to Exterior Aircraft Noise." Noise Control 5: 23–31, 60, September 1959.
10. Kryter, K. D. "Scaling Human Reactions to the Sound From Aircraft." Journal of the Acoustical Society of America 31: 1415–1429, November 1959.
11. BBN Report No. 656: Evaluation of Noise for Flight Operations of the Douglas DC–8 Jet Airliner with JT4A–9 Engines and Daisy-Ejector Suppressors. Agency: Port of New York Authority. Date: 26 October 1959.
12. BBN Report No. 657: Evaluation of Exterior Noise From Flight and Ground Operations of the Convair 880 Jet Airliner. Agency: Convair. Date: 19 November 1959.
13. BBN Report No. 683: Take-Off Noise Characteristics of the Boeing 707–320 Jet Airliner. Agency: PNYA. Date: 20 January 1960.
14. BBN Report No. 572: Reaction to Aircraft Noise (Draft Form). Agency: USAF. Date: June 1960.
15. Kryter, K. D., "The Meaning and Measurement of Perceived Noise Level." Submitted to Noise Control.

APPENDIX D. NOISE AND VIBRATION IN MISSILES AND ROCKETS

1. BBN Report No. 551: Methods of Flight Vehicle Noise Prediction. Agency: USAF. Date: October 1958.
2. BBN Report No. 554: Acoustic Design of Flight Vehicle Structures Facility. Agency: USAF. Date: October 1958.
3. BBN Report No. 659: The Noise Field of Jupiter Missiles. Agency: U.S. Army. Date: 28 December 1959.
4. Dyer, I. P., A. Franken and E. E. Ungar. "Noise Environments of Flight Vehicles." Noise Control 6: 31–40, 51, Jan./Feb. 1960.
5. BBN Report No. 704: Preliminary Study of Noise and Vibration on Jupiter Missiles. Agency: ABMA. Date: 17 February 1960.
6. BBN Report No. 679: Estimate of the Sound and Vibration Fields During Static Firing of a Saturn Vehicle and Analysis of the Damage Problem. Agency: ABMA. Date: 1 January 1960.
7. BBN Report No. 708: Procedures for Analysis and Solution of Aircraft and Missile Noise Problems at NAS Point Mugu, California. Agency: USN. Date: 15 June 1960.

The CHAIRMAN. Now the next witness you have, Dr. Bolt?

Dr. BOLT. Mr. Laymon Miller.

The CHAIRMAN. Mr. L. N. Miller, senior engineering consultant for Bolt Beranek & Newman, Inc., Cambridge, Mass. Happy to have you, sir.

STATEMENT OF LAYMON N. MILLER,[5] SENIOR ENGINEERING CONSULTANT, BOLT BERANEK & NEWMAN, INC.

Mr. MILLER. Thank you, sir. We are relying somewhat on your reading the testimony that Dr. Beranek has prepared, and I would like to comment in particular on some of the highlights that we would like to point out to you which we think deserve some emphasis here.

If you don't mind, I will refer to the testimony, the prepared statement that I believe you have in front of you, and will go very quickly through some of the particular items.

The CHAIRMAN. Fine. Just proceed.

Mr. MILLER. In particular, we might start on page 2 and I should comment, incidentally, that this prepared writeup was written in response to a list of questions which were presented to Dr. Beranek. So these comments are pretty much aimed at the questions asked. This will give us kind of a guidance and the vehicle for talking about aircraft noise in its various aspects.

On page 2, toward the bottom of the page, under an item A, we have jet engine noise and noise reduction. In this particular writeup we talk, in general, about the way noise is generated in a jet engine and, incidentally, we should point out that it isn't a simple matter of putting a muffler on the engine like you do on the automobile. This is a place where the noise is generated actually outside the engine, and so you have to worry about the treatment of the air that passes through and around the engine, as Dr. Abbott has discussed. This is a very complicated picture, but the point is that you don't simply put on a muffler like you do on your automobile because the noise isn't made within the engine, it is made outside the engine where this high-velocity air is shearing at the air around it.

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[5] Laymon N. Miller: Mr. Miller is a senior engineering consultant with Bolt Beranek & Newman, Inc. He received the Bachelor of Arts degree from Texas College of Mines, and the Master of Arts degree in physics from the University of Texas. From 1941 to 1945 he was research associate in the Underwater Sound Laboratory at Harvard University. From 1945 to 1954 he was successively assistant professor, associate professor and professor of engineering research in the Ordnance Research Laboratory at Pennsylvania State University. Mr. Miller is a Fellow in the Acoustical Society of America.

Mr. Miller's publications are as follows:

"Measurement Conditions Influencing the Front-to-Back Discrimination of an Underwater Hydrophone", JASA, January 1947.

"Acoustics Filter for Water-Filled Pipes" (coauthor), JASA, January 1950.

"A Review of ORL-Measured Torpedo Self-Noise" (coauthor), U.S. Navy Journal of Underwater Acoustics (Classified), April 1954.

"The Problem of Noise" Safety Maintenance and Production, June-July-August 1956.

"Noise Control for Offices Located near Production Machines and Mechanical Equipment Spaces" (coauthor), Noise Control, March 1957.

"Noise Characteristics of the Caravelle," Shell Aviation News, No. 231, September 1957.

"Acoustic Design for Transport Helicopters," (coauthor), Journal of the American Helicopter Society, October 1957.

"Comparison of the Takeoff Noise Characteristics of the Caravelle Jet Airliner and of Conventional Propeller-Driven Airliners" (coauthor), JASA and Noise Control, November 1957.

"Letter to the Editor: Response to Ken Eldred's Comments on Caravelle Noise," Laymon N. Miller and Leo L. Beranek, Noise Control 4, May 1958.

"Printing Machine Isolation," Laymon N. Miller and Ira Dyer, Noise Control 4, July 1958.

"Noise Levels Inside the Caravelle During Flight," Laymon N. Miller and Leo L. Beranek, Noise Control 4, September 1958.

"Product Quieting of a Pencil Shaping Machine," Laymon N. Miller and Robert M. Hoover, J. Am. Industrial Hygiene Assn., October 1958—reprinted in Facts on Factory Noise, No. 3, Associated Industries of New York State, Inc.

"Airports and Jet Noise," Laymon N. Miller, Leo L. Beranek and Karl D. Dryter, Noise Control 5, January 1959.

"Acoustical Design for Transport Helicopters," Laymon N. Miller, Leo L. Beranek and Harry Sternfeld, Jr., Noise Control 5, March 1959.

"Noise Characteristics of Some Jet Ground Operations," Robert M. Hoover and Laymon N. Miller, Noise Control 5, March 1959.

"Cooling Tower Noise," Laymon N. Miller and Ira Dyer, Noise Control 5, May 1959.

"Reaction of People to Exterior Aircraft Noise," L. M. Miller, L. L. Beranek and K. D. Kryter, Noise Control 5, 1959.

"Construction to Isolate High Intensity Noise," Laymon N. Miller, Architectural Record, December 1959.

"A Sampling of New York City Traffic Noise," Laymon N. Miller, Noise Control 6, May-June 1960.

This is a mechanism which is very difficult to control. Of course there are things being done about it, and all of the in-flight suppressors on our present 707, DC–8 and other jet aircraft reflect some of the research that has gone into jet noise suppression.

The one point I would like to highlight in this discussion on jet noise and future engine development is that it is inevitable. We believe, that we will be facing greater, higher engine capacity, greater engine thrust, more powerful powerplants in the future, and in some respects some of the noise from these powerplants will be greater. We hope that there will be sufficient engineering development so that some of the noise will be reduced.

The other speakers have mentioned the fact that the turbofan, which is our hope for the future, has its own problems. The turbine whine, the fan whine, is a problem that faces us all. We hope that there are possible solutions to that in the configuration of the engine and the aircraft, itself.

We would like to put out this plea, though, that with this increased engine power, that we not use all of that power to carry larger and larger aircraft continuing to fly low over our communities, but we would like to ask for a balancing of all of the factors involved and let this balancing take into account the fact that when we have increased power available, let's use some of it to pick up our airplanes and let them climb rapidly over the community and give us some advantage from the noise point of view to the community residents.

We believe that it is possible to achieve quieter engines in the future and we think that with major effort placed on that, rather than major effort placed only on engineering performance and aircraft performance, we believe that it is a reasonable goal to look for reduced noise output of engines, where we take into account the entire situation of the community response, the aircraft quantity, the airport surroundings, all of the factors that enter into airport noise problems and their solution.

May I ask you now to turn over to page 9 in this prepared statement. One of the questions that was asked was what was our feeling in regard to the application of some of the FAA rules, as applied to airport noise problems at the present time.

As you may know, we have been working with the New York Port Authority in their airport noise problems for something like 8 years, and of course we are very concerned with the problems surrounding the airports under the jurisdiction of the New York Port Authority, and most recently we have been acquainted with a proposed FAA regulation to be applied to New York International Airport. In particular we would like to give a few comments on that.

This testimony gives several of our specific comments relating to that, and we understand from reading in the paper that very soon, possibly this particular regulation will go into effect. We have made a rather bold statement on page 9 to this effect: that we believe that the FAA proposes to adopt noise reduction rules that will, on the average, result in higher noise levels in the communities than are allowed by the rules now in force by the Port of New York Authority.

This is a fairly strong claim, and we apologize for taking this position at this time, but we think that you will probably hear some of the testimony from FAA personnel at a later time and we would at least like to let you be aware of our views in this regard.

The CHAIRMAN. What do you recommend in that respect?

Mr. MILLER. Let me give you a few illustrations first. I admit there is no simple solution. But let me mention some of the problems that are involved. The FAA regulations, in general, do tend to reduce restrictions on the aircraft takeoffs. Let me give you an example in terms of this term "perceived noise level." For example, if we follow the FAA recommendation for takeoff procedure and consider a takeoff on a warm day with a 15-knot headwind, which is one of the conditions specified, if we permit no thrust reduction—at the present time the port authority requests that the airplanes go through a thrust reduction after they have reached a certain altitude to give what amounts to 5 or 6 db noise reduction on the ground as soon as the airplane goes over people—if we permit no thrust reduction, which is a possible interpretation of the FAA regulation, and if we permit full gross weight for the aircraft during takeoff, it is possible for the present family of 707's and DC–8's to generate noise over surrounding communities which fall in the range of 118 to 134 perceived noise decibels.

At the present time the New York Port Authority has set up regulations which are restrictive, we admit that, and this is one of the very serious problems with airline economic operations. Some of these rulings are restrictive, but nevertheless the rules do set up a limit of 112 perceived noise decibels. This indicates that under the FAA regulations the noise levels would actually exceed, by the order of 6 to as much as 22 db, this present restriction. We point out that the present restriction is based on extensive detailed study of the exposure of noise during the past few years in the vicinity of the New York International Airport, and it is the port authority's feeling that the noise restriction, noise limit of 112 PNdb, is a reasonable limit based on what people have been living with in the past.

It is their strong feeling that this number should not be exceeded by a large number, such as 10 or 20 db, even if we should accept the fact that the FAA regulation may allow thrust reductions over people, this gives us at most about a 6 db reduction, so we would still have the order of as much as 16 db over some communities under some instances.

Now these do not occur all the time. Admittedly, these are the extreme conditions, but generally these are rather untenable conditions and we would like this to be a part of our defense of some of the port authority regulations as they are in some contradiction to the proposed FAA regulations for this airport.

We might point out, incidentally, that whereas a weight penalty is one of the limitations now involved, at no point does the FAA proposal suggest the possibility of takeoffs at less than maximum takeoff weight.

This naturally is an economic penalty to the airline, but we believe it is one of the factors which the whole air industry must face if it is to live compatibly with our present airports. And we have heard the story that some of the modern-day jets have actually made obsolete many of our most modern airports in this country and in the world.

I am sure that you will hear, and it is pointed out very, very strongly in the FAA proposal, that safety is a very paramount factor in setting up takeoff regulations. We completely agree that at no time has

there ever been any attempt at compromising safety, but we do think that if this is as serious a problem as we feel it is, that some restrictions on takeoff weight may recover whatever safety compromises some of the people might be claiming for the port authority takeoff regulations at the present time.

We would also like to point out that we have been discussing mostly takeoff noise and yet the major complaint at the present time with jet airplanes is the landing noise. This is a very serious problem. We agree with the FCC regulation in recognizing that problem. We all recognize it. The NASA activity also pointed it out today. The landing noise is a very serious problem. Steeper descent angles, if they can be made possible, and work crosswind landing gear to make crosswind landing operations possible, may be required in the long-range future, in order to utilize in the best way possible those preferential runways which minimize exposure of people to landing noise.

This has been demonstrated in the B–52 which does have landing gear which permits crosswind landing conditions and it may become necessary in the future in our own commercial activity.

We have also spoken in other sections of this writeup here of future commercial supersonic aircraft, and we think that the NASA story has pretty much summarized that work. I don't think we need to go into any more detail. We have comments also on the sonic boom and on noise-induced fatigue and on the noise problems of large rockets and missiles. I would like to only comment on the large rockets and missiles to this extent: that it is being found in the present-day testing of large rockets that there is considerable low-frequency energy in the noise output of these noise sources and in times past we haven't had too much experience with low-frequency propagation over large distances. In this case we are talking about distances of 2, 3, 5, or 10 miles, where there is considerable possibility that atmospheric focusing might take place under some atmospheric conditions and meteorological conditions. And one of the areas of required study we think in the future in regard to missile bases and launching sites is the study of long-distance propagation of low-frequency sound. That is one of the factors that will be important in setting up onbase buildings, as well as in determining dimensions for missile sites in order to set up criteria, distances for residential neighborhoods nearby.

We have also made a comment on helicopter noise, because this is a vital possible problem in future operations in midtown aircraft activity. We can only emphasize the fact that this is a serious noise problem, and many cities have had to seriously restrict midtown helicopter operations because of the noise problem.

Thank you very much.

The CHAIRMAN. Thank you very much. We appreciate your statement. I would like to ask you a few questions. What do you mean by low frequency noise?

Mr. MILLER. In this case low frequency consists of almost subaudible, very low-frequency noise, the kind that you don't hear so much as you feel as a pressure pulsation on your body. Very low frequency. Also, because there is considerable energy in it, it is even capable of shaking large objects, such as houses.

The CHAIRMAN. What you would want to do then is to get away from low-frequency noises; is that right?

Mr. MILLER. Yes; naturally. In fact, this is important, because if we set up a missile site or a launching base, it is important to know just how far away you have to be, because land values are just tremendous, and if we have to go the difference between 4 and 6 miles, for example, in order to eliminate this potential hazard or potential disturbance due to low-frequency noise, the extra cost of that 2 miles of land is a significant factor and is important.

The CHAIRMAN. Is it preferable to try to work to get the noise to such a low frequency that you couldn't hear it?

Mr. MILLER. Not quite. It might still shake houses. A part of our story in more detail points out that there are many engineering advances that can be made to control noise at the base itself, and also possibly to control, in a better way, the low-frequency noise, so that we don't have such severe propagation of it. It is just that low frequencies in general are very hard to stop or to control. High frequencies are much easier. So when we are faced with low-frequency problems we have more troubles facing us.

The CHAIRMAN. Once you get the noise to have such a low frequency, you would not hear it. Would that be an advantage or would the vibration or the jar offset that advantage?

Mr. MILLER. The jar might offset the advantage, but we don't know criteria well enough on relative acceptability or tolerance or annoyance due to this low-frequency pulsation that you feel, as opposed to what you hear. I don't think we know the field that well.

The CHAIRMAN. That is something that we really could study with the possibilities that it would be very fruitful in this problem?

Mr. MILLER. I would think so, particularly as we get into more and more of the high-thrust engine situations.

The CHAIRMAN. Now the noise a dentist makes in drilling a cavity in your tooth is the low frequency which you don't hear; is that it?

Mr. MILLER. No. As a matter of fact, as they are going now to faster and faster speeds you are really getting higher and higher frequencies, more like the whine of this mosquito that we heard a while ago. What you might be referring to is the actual vibration, those drills hitting your teeth so many times per second, but as the speed goes up there is more high frequency rather than low frequency.

The CHAIRMAN. Then in the operation of drilling the tooth, you are not doing the drilling by using the noise; are you? You are doing that by using the bit? Is that correct?

Mr. MILLER. That is right. The noise is just an unfortunate association that goes along with the drilling.

The CHAIRMAN. I have read somewhere where they were actually using the noise, subsonic noises.

Mr. MILLER. I am afraid you are asking a leading question here.

The CHAIRMAN. Hypersonic noises. Doctor, they have turned to you for a solution.

Dr. KRYTER. Well, there are several problems here. First let me respond to your question about the noise that stops pain in the dentists' chair. This is an interesting development. The device is called the Audiac. Essentially, the dental patient has earphones on, and he hears music and rumbling noises like a waterfall. This sound does several things: one, it prevents the patient from hearing the drill; two, it apparently has a relaxing psychological effect so that he is distracted from what the dentist is doing; and, three, something

may take place in man's nervous system to block or stop the pain to some extent, though we do not yet understand the mechanism.

The CHAIRMAN. Do we have an object lesson that we could use at airports from that? [Laughter.]

Dr. KRYTER. Some people have talked about acoustic perfume, where you insert sounds or noises that tend to mask disagreeable noises. Mr. Miller mentions the home air conditioner could be a useful noise.

The CHAIRMAN. Nobody objects to that. Not down in my section of the country. They don't object to the noise of the air conditioners.

Mr. MILLER. The point is that noise can somewhat mask aircraft flyovers. So if you could supply all neighbors around airports with air conditioners you might have a point.

The CHAIRMAN. What about music, though? Letting them have a little music when the aircraft goes over?

Dr. KRYTER. Yes. Well, there are other rewards and compensations that can be played against each other here. Your first question was with regard to how sounds of different pitch, low frequency or low pitch versus a high, shrill sound, affect people. If you keep meaning constant, that is, if you don't have the mosquito, but you have two noises, one of which is low pitched and one is high pitched, but as far as the listener is concerned they are equally potentially dangerous, then he will say that the higher pitched sound is noisier, more disturbing than the lower pitch sound—he doesn't like it at all. And this is true along the whole frequency scale.

Up to about what we call four or five thousand cycles, the higher the pitch the more objectionable the sound is. This sounds like a contradiction of what Mr. Miller said, namely, that the low-pitch sounds were going to become a problem. But I think the point here is that the high frequency or high-pitched sounds are easier to control, the air attenuates them, they don't travel as far and the net result with some of these newer and proposed engines is that the only sound of appreciable intensity left may be, in some situations, the low frequencies.

Also, there is this unknown point of how people feel about the pulsating; very little is known about this, and I think more research, as you pointed out, is certainly in order.

The CHAIRMAN. So that from what you say, I understand that it is preferable to work toward the shrill, shreeky noise, the high-pitched noise, than it is to try to develop a noise with a lower frequency?

Dr. KRYTER. Yes, it is preferable to do that if you can then control it so that it does not reach the listener. But if we put ourselves, instead of the engineer designing the engine, in the position of the listener, it is better for him to have fewer higher frequencies to reduce the shrillness. As far as the listener is concerned, you want to reduce the shrillness rather than the lower pitched sounds.

The CHAIRMAN. Your conclusion is, it is better to work for a lower frequency sound?

Dr. KRYTER. At the listener's position, correct.

The CHAIRMAN. At the listener's position.

Damage to property; what about that?

Dr. KRYTER. My answer was for the so-called audible frequencies. When we get into these very low frequencies that Mr. Miller was speaking of, where you get shaking and resonances of structures, I would have to pass the microphone to someone else.

Mr. MILLER. The discussion really is on two kinds of noise here. The one point is that the type of aircraft noise we are now discussing, that we now experience, the low-frequency content of that noise is too low in intensity to have any damaging effects when the aircraft flys over.

It is a fact, as Dr. Kryter has said, that this kind of noise is less objectionable, less annoying, if it is low frequency, low pitched, than if it were high pitched.

In fact, we might even point out that the first inflight suppressors that came in on the 707–120, the first version of the 707 that came out, probably went too far in changing the low-frequency natural noise of a jet into very high-frequency noise, and made it more objectionable than it would have been if it hadn't gone up quite so far.

The next version of the 707 came down lower and is really an improvement, that is, the larger 707 with higher thrust output actually produces lower perceived noise levels than the earlier model of the 707 with its smaller engines.

The CHAIRMAN. Mr. McDonough.

Mr. MCDONOUGH. In your studies, what is the ultimate objective, to reduce the noise to the lowest level for the benefit of the human being, or the property damage that may result from low-frequency noise to physical property around the airport?

What do you find is the result of intense noises upon the human being?

Dr. BOLT. There are many effects. This is really a quite complex picture. This is the reason for this diagram.

You are living in a home under a flight path. If a very low plane goes by with considerable low-frequency rumble sound, it may shake the glasses on your counter, and you will be disturbed at that because you don't want the dishware to break.

Or a second case, the aircraft may be at some other height, making some other sort of sound, you may be having a bridge party and conversing, the noise goes by and you miss the punchline of the joke, and you are disturbed at that.

Or in the middle of the afternoon your wife is trying to get the baby off to sleep, and when it is just about asleep, the plane goes over and the baby never gets back to sleep. She is disturbed at that.

So on. There are many, many ways noise can impinge on people.

In the case of a sonic boom, you actually can break the windows in a house if the aircraft is below some height.

The broad objective of noise control is to make all the necessary adjustments in the system, the sources, the paths, the receivers, and so on, so as to bring all of these possible effects down to some tolerable level.

Actually, it is just a little more complicated than that. You realize that for every gain there is a loss. You have to pay somewhere along the line. So the real way to say it is you want to optimize the balance between reducing the effects of noise, on the one hand, and paying for it by more difficult operations, or by more dollars spent on an airport, or by less revenue and so on. You are balancing all of these factors in one very large complex system.

In other words, what I really want to emphasize is that the mission of noise control is not just to reduce the decibels somewhere; it is to solve the total system so that the balance, the compromise between

the adverse effects and the costs of reducing them, are brought into some judicial balance.

As you can see, this goes far beyond the field of acoustics.

Mr. McDonough. What does your study indicate on the physiological effects on the human being who is constantly subjected to these noises?

Dr. Kryter. Most of the data on the "noises of aircraft" variety that people are subjected to in real life indicate that the noises from aircraft do not directly harm the person in the sense that their intensity is such that it does not injure the ear and cause any permanent deafness, and with repetitions of the flyover, when the person understands that this is part of his environment—he knows there are so many flights going over each day—he becomes adapted, as we say, to these noises, the same way we become adapted to automobile horns outside our office, sounds of streetcars going by, sounds of the washing machine in the home.

People, physiologically, it has been demonstrated, do adapt to this. So the physiological manifestations for the average person become with adaptation nonexistant or rather low. However, there are indirect effects.

One is that the human being cannot adapt to sound of noise with regard to its interference with his hearing. In other words, when the airplane noise is there, of sufficient intensity, you do not hear what someone is saying to you, you cannot listen to your television or talk on the telephone. No amount of practice will permit you to do this, so you cannot adapt to the masking effect of sound upon your hearing, speech, or music, or whatever you want to hear.

Secondly, there is increasing evidence that you can adapt up to a certain level with regard to sleep. That is, you will get so you can sleep in very intense noises.

This is true in the Navy, for example in submarines spaces, where the noise level by decibel standards is quite high, 100 decibels, men learn to sleep there, they are happy—at least they are healthy. [Laughter.]

The physiological manifestations, not the psychological ones, are those that were recorded.

On the other hand, noise can indirectly cause physiological changes. For example, people may worry about how aircraft noise is influencing the value of their property. For this somewhat indirect reason their blood pressure may go up when they hear an aircraft fly over.

Yet at the same time, these indirect effects are real and have to be recognized. But perhaps this is a sufficient sorting out of the types of physiological effects that may be looked for.

Mr. McDonough. Thank you.

The Chairman. Mr. Bass.

Mr. Bass. Doctor, I come from an area where we are frequently subjected to sonic booms. This is up in southern New Hampshire.

Have you discussed before I came in here the nature of sonic booms and possible measures of better control?

Mr. Miller. It has been discussed by the group preceding our own, the NASA group. And they actually presented pictorial display here of the kind of sonic boom activity that might be expected if we come into commercial supersonic transports around the country and around the world.

Yes; we recognize that the sonic boom is a very undesirable attribute of supersonic flight. Operationally, there is some potential relief by the way you maneuver your airplane, what speed you fly at and how you climb out, and how you descend.

It appears, however, that we will have sonic booms for quite a while until we have solved some of the aircraft configuration problems that might—and this is a rather unlikely possibility—that might reduce sonic booms.

Mr. BASS. The airports operating in our area are military aircraft only. Were there recommendations made as to the best way to control this? I am thinking particularly of property damage that has been quite extensive in my area.

The CHAIRMAN. May I say this to Mr. Bass: that Captain Silberstein has some charts here that he will be glad to go over with you after the hearing. We have had them.

Mr. BASS. In the interest of time, I don't want to go into this, but this has been developed; has it?

The CHAIRMAN. Yes; it has been covered pretty well. However, if you want to ask any additional questions, of course there is no objection.

Mr. MILLER. High altitude flying is about the best solution we have right now. This means flights in the order of 70,000 or 80,000 feet or higher. That will give minimum sonic boom on the ground.

Mr. BASS. Just this one question: The Air Force has an arbitrary rule, as I have been told, that anything under 30,000 feet would be dangerous, but after 30,000 feet, the plane can fly at supersonic speed without any damage whatsoever.

Mr. MILLER. I think that is an oversimplification of the situation. Possibly tomorrow you might get some discussion on that point from a representative of the Air Force.

The CHAIRMAN. The Air Force tomorrow will have Dr. H. O. Parrack from Dayton, Ohio.

Mr. BASS. That is all I have.

The CHAIRMAN. I want to ask you several questions in respect to some aspects of noise.

Do we have sufficient information about the psychological or the physiological effects of noise to set up or establish design criteria?

Dr. BOLT. Well, we know a great deal about some aspects of the physiological and psychological effects. On some other details we don't know as much, but we know where the areas of ignorance are. That is a big first step.

Research that is now underway and that I am sure will continue in the next few years will undoubtedly close almost all the gap.

I would say that developing these criteria is not going to be the major stumbling block to finding solutions. The principal area in which more research is needed here is really social science, study of aspects of group behavior.

The CHAIRMAN. By social sciences, do you mean the types of noises that are so objectionable to people as a group?

Dr. BOLT. We are talking about the behavior of a group of people, a community, if you will, or a family, when they are getting frequent inputs of disturbing signals, whether or not a community reacts strongly or how strongly they react depends not only on how each

individual reacts to the noise but depends on interaction factors, social factors.

This is an area about which we know very little, and one of the important reasons why we should encourage more social science research.

The CHAIRMAN. Should that be done by the Government or should that be done by private groups, industry?

Dr. BOLT. At this stage, this field is really one of quite basic science and we would hope that scientists in universities would become more interested in this field.

The Science Foundation is certainly prepared and other agencies are prepared to support scientists who will come forth with good proposals.

However, there are also industrial and consulting groups, such as the National Opinion Research Center, who have made studies related to this and could make more if they were supported.

The CHAIRMAN. I think you testified that we are spending about $750,000 a year on this?

Dr. BOLT. Over the last 8 years, this is the amount that the National Science Foundation has put into basic research proposals which came to it, not aimed directly at the noise problem.

There is another number that is perhaps more significant. I have estimated, roughly, though I have not had an opportunity to obtain accurate numbers, that the order of $20 to $25 million has been spent on basic research on this problem during the last 15 years, on fundamental and mission-directed basic research.

The CHAIRMAN. By the U.S. Government?

Dr. BOLT. Yes. A very large part by the Air Force, NACA, NASA, Office of Naval Research, and other organizations.

Also, industry has put money into basic research as well as applied research and development.

This is a rough estimate of the magnitude.

The CHAIRMAN. Do you think out of that expenditure we have made some progress?

Dr. BOLT. Indeed we have. But we have also made very great progress in increasing the speed and thrust and power of our aircraft, and these two—this is the problem.

The CHAIRMAN. So when we progress in handling the noises, we retrogress in developing the airplane.

Dr. BOLT. Right now, the field of aviation is taking off better than the field of acoustics. [Laughter.]

The CHAIRMAN. One more question I would like to ask you, Dr. Bolt: Don't you think that we ought to begin to think about the criteria, however, for regulating the noise?

Dr. BOLT. Yes. The Armed Forces already have had considerable experience and have established and carry out certain requirements, certain criteria to control a number of their operations.

A number of airports have established criteria.

I think it is high time this problem was studied at a national level, and that rules or guidelines be issued which are applicable everywhere.

The one problem here to remember is that the particular number of, say, PNdb that turns out to be acceptable in one area is not necessarily the same number in another, because it depends on many factors, on

the terrain, the type of operation, the number of aircraft, the status of the community and so on.

So the regulation on a nationwide basis should not be given as just one number and require that there should be no more than this value. But rather, it should give the general principles and then guide each city and airport toward getting its appropriate rules locally.

The CHAIRMAN. Would you say it would depend on the type of construction? For instance, a noise entering a frame dwelling might be different from noise entering a brick dwelling.

Mr. MILLER. That is kind of hard to say, because you have all kinds of houses and all kinds of communities.

Basically, the kind of criterion that we have shot for in our work is "assume the windows are open," because in the summertime people have their windows open. The open window is a more serious problem than the type of construction.

The CHAIRMAN. Captain Silberstein?

Captain SILBERSTEIN. With respect to the criteria, do we have enough basic scientific research behind us upon which to develop the criteria, so that we know what we are looking for?

The engine manufacturers, for example, when they are designing new propulsion systems, do they have a set of parameters within which they have to wrap this design?

Are we in a position from a research and development point of view to establish a set of criteria for these people to work with?

Dr. BOLT. By and large; yes. We can make at least quite good tentative criteria for each of the several aspects of this complex problem.

We know pretty well which of the aspects that aren't good enough yet, and we know where we must direct some more basic research.

Where more work is needed to refine and establish them, we can establish tentative criteria and say something about their degree of reliability.

Captain SILBERSTEIN. What do you feel can be done to help solve the noise problem that hasn't been considered yet?

Dr. BOLT. Well, the last two or three paragraphs in the last page of my own testimony sums up my personal feeling about this, not speaking officially for any organization.

I think that science has really demonstrated to us firmly now that there will never be a truly quiet jet aircraft. Unless something extremely radical comes up that we don't visualize, any missile or aircraft vehicle that is pushed through the air by reaction or thrust motor is going to make noise.

Secondly, I am convinced that the amounts of noise reduction we can gain by refined engineering design will not be sufficient to reduce the noise down to the kinds of levels that any of us anticipate will be acceptable to communities over the long haul.

Therefore we come to the conclusion that looking at the system as a whole, the one thing that we are going to have to do more of is overall national planning of the system. Perhaps rethinking what are airports, where are they, how big are they, what do we do about the lands around them.

I know this gets into extremely complex regulatory problems, and I have no panacea to offer.

The CHAIRMAN. Colonel, do you have any questions?

Colonel TURNER. No, sir.

The CHAIRMAN. If there are no more questions, then, we want to thank you gentlemen for coming here this morning and helping us.

I think that we have had a very fine hearing this morning. Perhaps the committee can accomplish something by recommendations to help out in a very vital problem area.

If there is no objection we will adjourn until tomorrow morning at 10 o'clock.

(Whereupon, at 12:20 p.m., the subcommittee adjourned, to reconvene at 10 a.m., Wednesday, August 24, 1960.)

NOISE: ITS EFFECT ON MAN AND MACHINE

WEDNESDAY, AUGUST 24, 1960

HOUSE OF REPRESENTATIVES,
COMMITTEE ON SCIENCE AND ASTRONAUTICS,
SPECIAL INVESTIGATING SUBCOMMITTEE,
Washington, D.C.

The subcommittee met in room 214–B, New House Office Building, at 10 a.m., Hon. Overton Brooks, (chairman), presiding.

The CHAIRMAN. The committee will come to order.

This morning we have two witnesses; Dr. Richard Trumbull, Head of the Physiological Psychology Branch of the Office of Naval Research on Navy Programs Related to Aircraft and Missile Noise, and Dr. Horace O. Parrack, Technical Coordinator of Noise and Vibration Control of Wright Air Development Center, Wright-Patterson Air Force Base, Dayton, Ohio.

The first to be heard is Dr. Trumbull, and we will be very happy to hear from you, sir.

Do you have a prepared statement?

Mr. FULTON. This is the first coordinator of noise I ever met. [Laughter.]

STATEMENT OF DR. RICHARD TRUMBULL,[6] HEAD, PHYSIOLOGICAL PSYCHOLOGY BRANCH, OFFICE OF NAVAL RESEARCH ON NAVY PROGRAMS RELATED TO AIRCRAFT AND MISSILE NOISE; ACCOMPANIED BY CAPT. J. R. CARNES, OFFICE OF THE JUDGE ADVOCATE GENERAL; CAPT. W. JONES, BUREAU OF NAVAL WEAPONS AND BUREAU OF MEDICINE AND SURGERY; NELSON REKOS, BUREAU OF NAVAL WEAPONS; AND LT. COMDR. ROBERT DAGG, OFFICE OF CHIEF OF NAVAL OPERATIONS

Dr. TRUMBULL. Mr. Chairman and members of the committee: It is indeed a pleasure for these representatives of the Navy to be invited to appear before this committee this morning discussing a problem with which we have had a long acquaintance.

I am Dr. Richard Trumbull, Head of the Physiological Psychology Branch of the Office of Naval Research. I have prepared a detailed

[6] Dr. Richard Trumbull—Born: Johnstown, N.Y., Apr. 6, 1916. Education: Green Mountain Junior College, Union College, A.B., M.S., Syracuse University, Ph. D. Professional history: Assistant professor, Green Mountain Junior College, 1939–41; instructor, Syracuse University, 1941–43; chairman, Psychology Department, Green Mountain Junior College, 1946–48; instructor, Syracuse University, 1948–51; lecturer, Tulane University, University of Maryland. Military history: Aviation psychologist, U.S. Navy, 1943–46, 1951–53; present rank, commander, MSC, USNR–R. Other: Trustee, Green Mountain Junior College, 1948–51; U.S. Member of Noise Committee of Aero Space Medical Panel; Advisory Group for Aeronautical Research and Development, NATO; Sigma Xi, Psi Chi; licensed by State of Maryland as psychologist. Membership: American Association for the Advancement of Science; American Psychological Association; Aero Space Medical Association.

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statement on the Navy's history of Research, Development, Test, and Evaluation related to Aircraft and Missile Noise which might be inserted in the record, and I have a brief summary statement of the highlights which I would like to read.

The statement submitted for the record was prepared to provide this committee with an overview of how the Navy first became confronted by problems of aircraft and missile noise and some of the measures undertaken to alleviate them.

It presents the relationships between bureaus, their laboratories, contractors and research institutions as each contributes to such an effort.

Further, it presents the interrelationships between these Navy activities and those by the Air Force, Army, other governmental agencies and industry where common problems found us on common ground.

By 1952, continued increase in power requirements for newer and heavier aircraft, operating from carrier decks, demanded further consideration of protection for personnel and maintenance of communication in areas of high-intensity noise.

Preliminary, crude measurements in a Bureau of Medicine and Surgery survey of noise spectra and intensities during launch and of deck crew hearing thresholds convinced the investigators that the 130–135 db levels measured were associated with demonstrable hearing loss.

It was recognized that the available equipment for sound pressure as well as audiometric measurement left much to be desired but the promise of newer jet engines with higher thrust demanded immediate action.

A second study found levels over 140 db and the first indication of nonauditory effects. This evidence of complexity resulted in the organization of an interdisciplinary committee, the Armed Forces-National Research Council Committee on Hearing and Bio-Acoustics at the recommendation of the Committee on Medical Sciences of the Research and Development Board of the Department of Defense and the endorsement of the National Research Council Committee on Hearing.

One of the first working groups under CHABA, as the committee has been known, produced the BENOX report—"Biological Effects of Noise, Exploratory"—based on studies of new aircraft at Patuxent River and on board the U.S.S. *Coral Sea* under operating conditions.

Personnel from the various Navy bureaus, the Air Force, the Army, and civilian life participated in this evaluative study and the recommendations for action which resulted.

The point had been made. Broader and new research and development efforts were started on personnel protection and noise control. In the former, instructions for use of available ear protectors and helmets were issued while improved ones were sought. Operational procedures were altered. Acoustic treatment of personnel areas was prescribed in further instructions. Barriers, deflectors, and other attenuators now appeared on lists of new projects.

It is impossible to enumerate the various approaches undertaken during the following years. New concepts and equipment were demanded in every aspect. New earplugs and muffs streamed into laboratories which had to devise ways for measuring their efficiency.

Today, we have earplugs which provide up to 30-decibel attenuation in the 500-cycle-per-second region in the development stage, which is a major accomplishment in this area.

New sound level meters, capable of registering peaks of exposure and analyses of spectra have been developed. Accurate determination of hearing loss demanded baseline audiometry and continued monitoring in association with levels and duration of exposure. Appropriate directives have initiated such procedures. This type of audiometry also required acoustical treatment for spaces on board carriers. This now is being accomplished.

Getting closer to the source, new understanding of the origins of the different frequencies became necessary. Deflectors could not answer all of the problems and various suppressors now appeared.

A project was started at the Aeronautical Engine Laboratory for the purpose of designing, fabricating, and testing several types of portable jet-exhaust silencers for ground use with afterburner jet engines.

Five methods for reducing jet-engine noise were considered for their individual or combined contribution to solving the problem. These were atmospheric attenuation, source reduction, directivity, frequency shift, and cancellation.

Unfortunately, most of the inflight-noise suppressors, mixing the highly turbulent, high-temperature exhaust gas stream with the cool ambient air surrounding the jet, also imposed drag, weight, and engine performance penalties. Losses in thrust experienced with inlet and exhaust suppressors demanded turning to other techniques.

The most promising aspect as of now is that found in turbofan engines where their large mass of low temperature, low velocity fan air lends itself to acoustical treatment. This may result in up to 17 decibels of noise reduction.

Meanwhile, military and civilian efforts on ground suppressors were rewarded. We now have such suppressors capable of providing approximately 30 decibels of suppression while withstanding afterburner heat for 15 seconds without cooling water.

Additional research and development continues on another suppressor that acoustically treats noise generated from both the jet-engine inlet and the exhaust.

It is expected that approximately 45 decibels of suppression will be possible with these devices.

It is believed that by 1962 the Navy will have ground devices providing 45 to 50 decibels of suppression for use on engines of up to 20,000 pounds of thrust.

The Navy's progress with inflight and ground suppressor development is as important to naval air station and civilian communities near which the Navy operates as it is to our carrier community.

During the same period carrier personnel were receiving attention, the Bureau of Yards and Docks faced problems in location of quarters in relation to runways, test stands, and warmup areas.

By 1956, a program of noise surveys was underway, establishing zones for housing. Over 34 such surveys now have been completed and station quarters have been built with these restrictions.

The construction of stations and extensions of runways brought another community aspect under consideration, even as did the con-

stant encroachment of communities around naval installations already present.

Here diplomacy, compromise, and education have held a problem at a low level. However, we are well aware that community reaction is a major problem today so long as present patterns continue.

We do not know all of the variables involved. We have little control over many of those we do know. We can change operational procedures just so far. We can provide ground suppressors capable of reductions up to 40 to 45 decibels. We can use natural attenuators such as hills and introduce others such as trees and shrubs. When all of this is done, however, we still will need distance.

If the missile problems receive very short discussion here, it is because we feel that most of our education in aircraft noise is translatable. Our operational missiles are not exceeding present aircraft noise levels nor are they near those of gunfire.

Our Pacific Missile Range will be keeping pace with newer and more powerful thrust engines. Terrain is a natural ally where launching pads can be built in deep ravines in the center of vast stretches of land over which we exercise control.

This will be the first time distance has been in our favor. In contrast to the confinement of the carrier deck where we started, this will be a welcomed change. We would be very happy to answer any questions you would like to ask, Mr. Chairman.

The CHAIRMAN. Thank you for your statement, Doctor, which we appreciate very much.

Now, you refer to 45 or 50 decibels which might be the amount of reduction of sound by use of suppressors. What would be the cost of such a program?

Dr. TRUMBULL. Well, at the present time, Mr. Chairman, we have such attenuators available. The ground-suppression program for the Bureau of Weapons has involved two major expenditures. In 1958, a total of $779,000, and in 1960, $504,000.

The CHAIRMAN. In 1960 how much?

Dr. TRUMBULL. Five hundred and four thousand dollars.

The CHAIRMAN. Five hundred and four thousand dollars.

Dr. TRUMBULL. Yes, sir.

The CHAIRMAN. Counsel suggests that I ask you this. What would be the cost of one of these suppressors?

Dr. TRUMBULL. Might I refer this question to Mr. Nelson Rekos from the Bureau of Weapons?

The CHAIRMAN. Fine.

Mr. Nelson Rekos?

Does the reporter have your full name?

Mr. REKOS. Yes, sir.

The CHAIRMAN. What is your title?

Mr. REKOS. My name is Nelson Rekos and I am the technical assistant to the plans and programs officer in the Powerplant Division of the Bureau of Naval Weapons.

The 45 to 50 decibels of suppression refer to both suppressors on the exhaust end and suppressors on the inlet end, plus the use of sound fences and the use of insulating blankets. The only cost that we have at the present time is on the exhaust suppressor. We estimate that the cost of the exhaust suppressors will be no more than $12,500.

As far as the inlet suppressor, we are evaluating these at the present time and we don't have too good an idea of the cost.

The CHAIRMAN. What are the major noise problems confronting the Navy in operating jet aircraft and guided missiles from ships?

Dr. TRUMBULL. Mr. Chairman, the major problems have been those of providing adequate protection for the personnel who have to be within the immediate area during the launching of the aircraft, primarily, and, more recently, the missiles.

The extensive program that has been undertaken through the research programs under contract, the laboratory work in the Bureau of Medicine and Surgery and Bureau of Naval Weapons, has been aimed at the development of earplugs, earmuffs, and helmets which will lower the exposure to the individual, at the same time maintaining the best possible communications.

The present equipment will meet our needs with the aircraft we are now flying from our carrier decks.

The missile development has been followed very closely with noise spectra analyses being done on every firing of the missiles, and at the present time we have no indication that positions in which a person will stand during an operation will be exposed to any higher level than we have already experienced with our aircraft.

Indeed, the closest that an individual will operate on a cruiser now firing some of our missiles will have an exposure level of 150 decibels. And this is on the outside of an area where he will be on the inside already accomplishing some attenuation from the structure within which he is housed.

The CHAIRMAN. How does the effect of sound from missiles compare with the sound from the firing of a 12-inch or 16-inch gun?

Dr. TRUMBULL. Mr. Chairman, the sound level is not as high in the initial burst. Though it is of longer duration, the individuals who have this under their cognizance are convinced that the gunfire noise that we have already experienced is going to be in excess of anything we will experience with the missiles. And we do have sound profiles on these—comparative profiles of the different types of guns which are now firing and the missiles.

The CHAIRMAN. Did you say that it would not be in excess?

Dr. TRUMBULL. It will not be in excess, sir.

The CHAIRMAN. It will not be in excess. So it should not be a greater problem than the problem we already face in the use of heavy guns. Is that right?

Dr. TRUMBULL. That is right.

The CHAIRMAN. The sound is more prolonged with the use of missiles than with firing a gun?

Dr. TRUMBULL. Generally. It also has a little higher frequency, sir, and of course shifts in frequencies then mean differences in the types of attenuation you need for personnel protection.

But the profiles of these are of such nature that there has been no concern expressed at all by those who control it.

The CHAIRMAN. Does it have a longer duration?

Dr. TRUMBULL. It does not than some of the major heavier guns as the Navy has been firing; no, sir.

The CHAIRMAN. So the Navy then has had experience in handling problems of sound of this character due to the fact that they have handled very heavy weapons?

Dr. TRUMBULL. Yes, sir.

The CHAIRMAN. And that experience should be of great help to the Navy and to all of us, too, because of cooperation in handling this problem of sound. Is that true?

Dr. TRUMBULL. I believe that is right, sir.

The CHAIRMAN. Now, what cooperation does the Navy extend to NASA and industry generally in the handling of these noise problems?

Dr. TRUMBULL. Mr. Chairman, it is difficult in many respects to try to find where one of the services has left off on this and even some of the civilian agencies. As early as the NACA people were involved in this, in the early 1950's, you will find cooperative efforts were undertaken. In one of the major meetings in Chicago, combining the Committee on Hearing and Bio-Acoustics and the NACA, we dealt with the community noise problem. This, I believe, is rather characteristic, that during those earlier years there were relatively few people really concerned with these problems and, as a result, the communications between these people was very fluid. This has been maintained, primarily, through the Committee on Hearing and Bio-Acoustics and duplicate membership on noise committees in the National Academy and in professional societies.

The CHAIRMAN. Do you have a joint committee with NASA on this subject?

Dr. TRUMBULL. Yes, sir. NASA is now a member of the Armed Forces Committee on Hearing and Bio-Acoustics.

The CHAIRMAN. Yes. So that you have daily contact with officials of NASA on this subject where needed?

Dr. TRUMBULL. Yes, sir.

The CHAIRMAN. Tell us about this CHABA committee, what it does and who makes up the committee?

Dr. TRUMBULL. The Committee on Hearing and Bio-Acoustics was established in recognition of this problem in the early 1950's and the constitution is roughly one-third from each of the three services and the military representation, then, being paralleled by recommended membership from the National Academy of Science, civilian representation.

In addition, there are liaison members from FAA, from the other agencies in the country. The Atomic Energy Commission also had some problems in this area, and we enjoy an extensive relationship with those committees as well.

Individuals can bring to this committee any problems which they have in the area, related to noise or hearing, itself, communications, low-level vibration, and working groups can be structured to look into the problem. If it is a relatively simple problem and it is just a matter of the data being available but not available in the right hands, there is a means for providing this sort of information as rapidly as possible to answer the question which has arisen.

The CHAIRMAN. The Navy uses a great many helicopters. Do you have a problem of noise with the helicopter?

Dr. TRUMBULL. If you will, Mr. Chairman, I will refer this question then to Capt. Walton Jones who is the Bureau of Medicine and Surgery liaison officer with the Bureau of Naval Weapons.

The CHAIRMAN. Captain Jones?

Captain JONES. Mr. Chairman, I am Capt. Walton L. Jones, head of the Aviation Medical Equipment Section in the Bureau of Medicine

and Surgery and liaison officer to the Bureau of Weapons on the same subject.

We do have some problems with helicopters, primarily in the low-frequency range. The passengers, as it were, troops that are being transferred, have experienced in some of the tests we have made, a low-grade hearing loss and we have taken steps to provide them with attenuators to wear while they are in the helicopter. The helicopter pilots and crewmen, of course, wear the normal flight equipment, which our other aviators wear and this equipment has attenuating properties.

The CHAIRMAN. Now, with reference to that problem where hearing is damaged, are medical discharges resulting in hearing loss increasing or decreasing?

Captain JONES. Mr. Chairman, along in 1948 or 1949 it was lower than it is today. It increased in 1950 and 1951. Now it appears to have leveled off. I think this is a result of our concentrated efforts in this area, to make sure it does not go higher.

The CHAIRMAN. It seems to me the Navy is really using not so much the method of reducing sound as they are using a method of protecting the ear from damaging sounds.

Captain JONES. Yes, sir.

The CHAIRMAN. Is that correct?

Captain JONES. Yes, sir; we are using both the equipment that the man wears and the enclosures he may be in or behind. We sound first, if possible, these intervening structures.

The CHAIRMAN. And you are depending on that, really, to protect the men?

Captain JONES. Yes, sir. And then, also, we have our ground suppressors.

The CHAIRMAN. But in the final analysis, to protect the men, you are really using these ear protectors, rather than depending on the suppression of sound, is that correct?

Captain JONES. Actually as the noise gets higher, Mr. Chairman, we have to use both.

The CHAIRMAN. Do you expect the noise to be intensified with future naval developments?

Captain JONES. It has in the past, sir, and we expect it probably will be in the future.

The CHAIRMAN. So as we make progress, technically, we move backward in the handling of noises, don't we?

Captain JONES. Yes, sir. We have to double our efforts.

The CHAIRMAN. And we have to be even more diligent and vigilant in protecting our people from sounds?

Captain JONES. Yes, sir.

The CHAIRMAN. If any member of the committee has any questions, please feel free to ask them.

Mr. FULTON. When you are through, I have a couple.

The CHAIRMAN. All right, Mr. Fulton.

Mr. FULTON. The question concerns not only the various ships but the submarines. How about the Polaris? Is there a noise problem on the missiles of the Polaris?

Dr. TRUMBULL. No, sir. The primary noise source we have on the Polaris, so far as the personnel in the submarine are concerned,

is the same type of noise we have experienced with the launching in torpedo tubes up to the present time.

Mr. FULTON. Is it because it is simply compressed-air launching, you don't have the problem on that type?

Dr. TRUMBULL. Yes, sir.

Mr. FULTON. Is there any possibility on ships to move over to compressed-air launching?

Dr. TRUMBULL. Measurements have been made on all of these firings with the Lockheed missiles when they are fired at the normal altitude, 75, 50 feet above the deck. And this also is, we find happily, below the levels we have already been experiencing with aircraft.

Mr. FULTON. Have you made any check on World War II, for example, as to the extent of loss of hearing on carriers? I was on a carrier, myself. Has there been any research done to see the extent to which this loss of hearing has shown up?

Dr. TRUMBULL. I doubt if there have been any studies on this, sir. One of the major problems we have which we faced in the early 1950's is that we did not have adequate baseline data on the people as they were brought into the services. And, as a result, you would question any discharge that then later on indicated a hearing loss, because you weren't certain where you started in the first place. It is one of the odd things of this whole problem that in dealing with the high intensity noise problem with aircraft we have found ourselves going way back to very basic audiometry, developing new audiometers and firming the whole baseline because of the possibility of claims for service-incurred disabilities. And as a result, I think any figures one would try to use from World War II would be questioned and questioned on this basis.

Mr. FULTON. The question then is not only of the high decibels of noise, but the use of low-decibel noise. What are you doing on suppressing noise at its source, mechanical noise, for example, in water, or using noise as a method of identification? Taking the pattern, say, of a foreign submarine and checking to see whether it fits certain requirements for identification.

What have you done in those fields?

Dr. TRUMBULL. Frankly, sir, I am not prepared to answer that question.

Mr. FULTON. We are always talking as if noise is not a benefit to us. I don't think there is such a thing as a noiseless ship or a noiseless submarine, is there?

Dr. TRUMBULL. That is right.

Mr. FULTON. So that for identification, noise is a gain rather than a loss.

The CHAIRMAN. Will the gentleman yield? Where you state, Doctor, that you are not able to answer a question do you mean that it is classified?

Dr. TRUMBULL. No, sir.

The CHAIRMAN. You just don't have the answer available?

Dr. TRUMBULL. No, sir.

Mr. FULTON. You were speaking here of the multi-disciplinary aspects of the problem. You mean in Navy language that they are scientific disciplines, not military disciplines?

Dr. TRUMBULL. That is right, sir.

Mr. FULTON. Are there any established rules now for these carrier deck personnel on requirements that they must use certain equipment or is it simply that they do it if they want to?

Have you established—you could almost call it—parameters that are required for deck-handling procedures on carriers?

Dr. TRUMBULL. Yes, sir, procedures were altered upon finding the levels to which the men were being exposed and in 1955 a Bureau of Medicine and Surgery instruction was issued, maintaining the hearing of individuals, the types of protectors which would be available. Educational movies were made for showing to deck crews acquainting them with the problems and also the manner in which they were to use their equipment, and a system of audiometry was developed wherein those who were known to be exposed in areas above 95 decibels were periodically checked then for any possible hearing problems and those who were in areas above 85 decibels were recommended for this type of treatment.

Maybe Captain Jones would like to speak to that.

Mr. FULTON. That is a good answer. On the toleration of noise, there is the aspect that you become used to it through repetition. On a biological basis, does the continuation of the noise that you become accustomed to make one adjust to it as a physical adjustment or is that not possible? Is our human body able to adjust to these noise problems physically, or do we just become used to it through a deadening of our eardrums and our mental processes?

Dr. TRUMBULL. Sir, yesterday afternoon or yesterday morning, I believe you had a representation here from the individuals who were concerned with the community reactions and undoubtedly they spoke of the complexity of this problem. It isn't so simple—in a laboratory we can take individuals and test their hearing and find out what is happening over a continued exposure, but one of our problems is taking this from a college laboratory out into a community where what the individual is doing at the time, the types of things they have on their mind, what the noise means to them, the fear aspect, and so forth, these all add to a matrix of such complexity that I don't know as I would want to lift the biological aspect alone or physiological adaptive aspect out.

Mr. FULTON. It raises quite a basic question, and that is the adaptability of the human race to the noise conditions we can see in the future.

First, are we going to be able to adapt our physical mechanisms?

Secondly, if people don't adapt, maybe all of us in the world are going to lose a certain part of our hearing. We are born with it, but we might immediately lose it. Which is it going to be? Is man able to adapt or are we going to have to limit noise by law in this country and internationally on the decibel rate? Perhaps there should be an automatic limit, that you can't go above?

What do you say on that basic, philosophical question?

Dr. TRUMBULL. I believe I would not count on the human organism making this sort of adaptation.

Mr. FULTON. You have no evidence of adaptation of hearing facility through continued noise exposure?

Dr. TRUMBULL. Not that I would want to translate into community or the normal everyday adjustments; no, sir.

Mr. FULTON. You have found that on continued noise exposure at a high decibel level, that it does cause hearing facility loss?

Dr. TRUMBULL. That is right.

Mr. FULTON. The ability to either understand or to distinguish sounds. That does occur; doesn't it?

Dr. TRUMBULL. Yes, sir.

Mr. FULTON. Do you think it will be an overall problem, then, of the elimination of noises, for example, in large congested or metropolitan areas? And that includes planes, missiles, automobiles, horns, every kind, construction?

Are we coming to the overall saturation point of noise in our communities? Maybe you people are just adding on a few more things? Maybe it is a buildup of a certain level of noise. For example, I am very conscious of noise in this room. It is not a quiet room. When you add a buildup of noise, adding on an overlay of a basic jumbled noise such as you hear in New York City in the morning, are we arriving at a point that exceeds what humans can tolerate?

Dr. TRUMBULL. Sir, I think part of the answer, philosophical though it may be, is that reflected in the types of restrictions which have been instituted at the present time. We recognize that you can't expose individuals to high noise levels all during the night and disturb their sleep and then expose them to the same level of noise in the daytime. There is a cumulative effect beyond which we would certainly not expect to expose individuals.

Mr. FULTON. Is the Navy, on its runways, its takeoffs and its ascents, trying, near industrial and metropolitan areas, to limit noise practically? I hate to mention Pittsburgh again, but we have a very large airport there with jets and we have a very large Reserve Force. I was talking this morning with the people on our staff. They are F–86's. They have to be revved up, returned to idle power, switched to manual fuel control and revved clear up again and then takeoff. You get 100 people doing that three times and you get quite a bit of community reaction from several miles away.

Now, are you taking proper procedures now to limit the effects of noise under practical working conditions on Navy installations?

Dr. TRUMBULL. If I may, sir, I would like to refer this question to Lt. Comdr. Robert Dagg of the Office of the Chief of Naval Operations.

The CHAIRMAN. Commander.

Lieutenant Commander DAGG. This problem is a local command problem normally, and the local commanders do take these steps. They issue instructions pertaining to the height of the traffic pattern around the field and to the direction of takeoff that jet aircraft take, normally directing them away from congested areas, pointing out particular sensitive spots like hospitals and schools and so forth that are to be avoided.

We are limited to the amount that we can reduce the before takeoff run up of jet aircraft. It has to be done before the aircraft takeoff. They try, where they can, to utilize an area as far away from nearby congestion as possible.

Mr. FULTON. Do you have any overall Navy program for this purpose or is it just all left to the local commander?

Lieutenant Commander DAGG. There are two Navy instructions that have been issued on the Chief of Naval Operations level directing the commanding officers to take these steps.

Mr. FULTON. We that represent metropolitan areas that have large jet airports are really subject to quite a bit of criticism. Don't underestimate the community reaction to noise because it is arriving at the upper level of toleration.

That is all; thank you.

The CHAIRMAN. Following the line of Mr. Fulton, it is noticeable that in communities with large airports, the public is prone to build homes and residences all around the airport in spite of these noises; isn't that correct?

Lieutenant Commander DAGG. Yes, sir; very true.

The CHAIRMAN. Doesn't that intensify your problem?

Lieutenant Commander DAGG. Yes, sir. Generally speaking, our airports were originally built pretty much out in open country. Of course, when they become operational, they seem to attract communities and homes. They just seem to march up to the edge of the airport and then we start getting our complaints.

The CHAIRMAN. That is correct. Thank you.

Mr. SISK. Mr. Chairman.

The CHAIRMAN. Mr. Sisk?

Mr. SISK. Could I pursue that question a little further. I don't know whether you have any information or made any study of this or not. I agree that this was what was happening at one time. But now around these bases in my area in California, real estate values have dropped deplorably and people find their homes unsalable. Isn't this situation being reversed?

I mean in the Navy's problems across the country—I am thinking now of naval air stations and places like that, in communities—to what extent are you getting complaints from this standpoint? That rather than developers actually going into the areas, how about complaints that you have destroyed the value of the existing property?

Lieutenant Commander DAGG. We have some; yes, sir. Recently we have had some complaints from people saying that the values of their real estate have declined or they are having trouble selling their home because of this.

Mr. SISK. Mr. Chairman, if I could at this time, I would like to pursue one question or one problem with Dr. Trumbull.

The CHAIRMAN. Go right ahead.

Mr. SISK. I don't know to what extent in your own work that a study has been made of this, but I am interested in knowing the extent of the damage caused by noise. I am thinking now of plant life, organisms other than human, and structural damage to actual equipment.

To what extent scientifically has this problem been looked into?

I might say, Doctor, that we have just had rendered a rather interesting court decision in my hometown in California which started out as a multimillion-dollar lawsuit. It was originally against North American Aircraft and the city.

They were being sued jointly by a company which makes and manufactures wine. I think my district makes more wine than any other place on the North American Continent. This lawsuit has gone on for some 3 or 4 years. Finally a decision was rendered within the last few days. It is quite interesting. I am not trying to get you involved in whether the court's decision was right or wrong. I am

just interested to what extent scientists, as such, have actually investigated the effects of continuous noise of this level.

The lawsuit was due to North American's modification of jet aircraft and the constant testing of engines. Added to this were landings and takeoffs by B–52's on the same airport.

Can you make a comment on that at all? I am thinking now of its effect on lower life, on plantlife, on organisms and things of that kind.

Dr. TRUMBULL. Sir, I am afraid that raises just about the same type of questions we have with people. You would have to get back and know exactly what the spectra were, what intensities were and for how long and, unfortunately, go back and do it over again with whatever group you are concerning yourself with, be it a biological specimen of some type or a human.

You also have the problem of other things which would contaminate a claim of this type. Types of fuels you have, atmospheric conditions in the area that might also be altered by the noise. There might be other variables that one would have to take out, too.

Frankly, in answer to your questions, I do not know of any studies where noise has been imposed upon plantlife systems of this type to find out whether it alters the production or taste or sweetness or whatever else is involved in the processing of the biological plant.

Mr. SISK. Thank you.

The CHAIRMAN. May I ask you this, Doctor? It seems to me there are two possibilities of damage by noise. One is long continued noise and the other is high frequency or shock? Would you call it shock?

Dr. TRUMBULL. Impulse-type noise.

The CHAIRMAN. High impulse from noise.

Now, the men in the Navy, are they more apt to be injured in their hearing by low frequency, long continued noise that produces a fatigue or would you say the high impulse might be the more provacative for injury to the hearing?

Dr. TRUMBULL. Mr. Chairman, you will find in the detailed report that we developed an acoustic trailer to take on board our carriers to allow, as immediately as possible, a measurement of hearing loss after the aircrew had been handling the launching of aircraft.

In the instances where we found some indications of hearing loss, we kept running into the fact these same people used .45's, small arms, side arms, exposing them to high impulse type of noise. This actually reached such a point that none of the results we had on hearing loss on the carrier were considered tenable until we went back and studied this sharper type of impulse noise of the .45. Generally I think the belief is that this is more damaging.

The CHAIRMAN. In other words, the sharp report of a .45 pistol is more damaging to the hearing than the heavy continuous noises?

Dr. TRUMBULL. We presently have more claims of that type, sir.

The CHAIRMAN. So that you wouldn't feel, for instance, that the hearing of the people of Los Angeles would be injured by the operations of North American or another airplane plant, by continuous noises of the lower decibel rate?

Dr. TRUMBULL. The figures on this type, I think, Mr. Chairman, might be given to you this afternoon. I don't want to ask Dr. Parrack to pick up some of the questions necessarily from this morning's session. But there were some regulations established in terms of time of exposure and intensity, where you are trading time over against the intensity of the noise to which the ear is being subjected.

The Air Force concerned itself with this quite extensively, I know, through some of the work they had with CHABA.

The CHAIRMAN. We are reserving an hour for him, from 11 to 12.

Dr. TRUMBULL. Yes, sir.

The CHAIRMAN. Put it this way then: In reference to damage to material, would the damage apt to be more severe from long continued noises or from sharp, high frequency noises?

Dr. TRUMBULL. If I may, I would like to refer this to Mr. Rekos, of the Bureau of Naval Weapons.

The CHAIRMAN. Mr. Rekos?

Mr. REKOS. Mr. Chairman, the time period that the aircraft structure is subjected to this noise has a good bit to do with how it is going to fail. If you subject any test panel or aircraft fuselage to a noise level over a long period of time, it will fail. As the intensity of the noise increases, this time period decreases.

The CHAIRMAN. So it is a ratio; isn't it?

Mr. REKOS. Yes, sir.

The CHAIRMAN. The higher the frequency, the shorter time is required to do damage.

Mr. REKOS. Not so much the higher the frequency, as the intensity and frequency combined. The lower frequencies are actually, as far as structures are concerned, I believe are more damaging because they have more energy in them and we get rather large pressure fluctuations on our skin structure.

The CHAIRMAN. How do you differentiate between high frequency and the lower damaging frequency? When you refer to high frequency, you are referring to the sound wave frequency; is that it?

Mr. REKOS. Yes, sir.

The CHAIRMAN. And when you are referring to low frequency, it is a much lower frequency sound wave that you have in mind?

Mr. REKOS. No. A sound wave is made up of low and high frequencies. One of our principal concerns is the lower frequency because that is the wavelength that has more energy and consequently may cause more failures.

The CHAIRMAN. Is that an element of sound, the wave energy in the low frequency that causes the vibration or the shock? Is that an element of sound, itself?

Mr. REKOS. Yes, sir.

The CHAIRMAN. It is a part of the low-frequency sound wave?

Mr. REKOS. Yes, sir.

The CHAIRMAN. And it produces energy resulting in shock or certainly in vibration?

Mr. REKOS. Yes, sir.

The CHAIRMAN. The vibration, itself, produces the damage?

Mr. REKOS. Yes, sir.

The CHAIRMAN. In handling aircraft, you have that sound continued over a long period of time. Is it the experience of the Navy that this results finally in serious damage to the aircraft in the form of metal fatigue?

Mr. REKOS. Yes, sir; it has.

The CHAIRMAN. And in the higher speed aircraft, such as jets, has that damage been increased?

Mr. REKOS. Yes, sir; it has. Our latest aircraft have experienced structural failures, in the area of the jet exhaust. However, these

failures can be treated, engineeringwise, by using smaller panels, so they are not subjected to large amplitudes, by using materials that are able to withstand sonic fatigue, better materials, using heavier gage material, using different types of fasteners, using mastic compounds to dampen out this noise.

The CHAIRMAN. And different types of metal?

Mr. REKOS. Different types of metal; yes, sir.

The CHAIRMAN. Are all metals more or less responsive to the same sounds?

Mr. REKOS. In different manners, but they don't respond the same way. Some metals can withstand vibrations or sonic fatigue better than other metals.

The CHAIRMAN. Have you noticed any difference between the metal fatigue in jets and that experienced by rockets?

Mr. REKOS. I don't know, sir.

The CHAIRMAN. So we don't know up in space what metal fatigue we may have as a result of operating in space from different types of metals?

Mr. REKOS. We don't have enough experience on that, sir.

The CHAIRMAN. You haven't had the experience. Is this metal fatigue in high-speed jets a very serious problem with the Navy?

Mr. REKOS. Well, it has been a serious problem, but we believe we can handle this engineeringwise and we actually have been handling it in our latest jets.

The CHAIRMAN. So you think you are gradually whipping it?

Mr. REKOS. Yes, sir.

The CHAIRMAN. As far as damage to material?

Mr. REKOS. Yes, sir.

The CHAIRMAN. Now, would that problem be translated to those that live, like Mr. Sisk suggests, around an airport that uses a great deal of jet equipment? Would the homes around there be affected by fatigue to the material?

Mr. REKOS. I believe so; yes, sir.

The CHAIRMAN. You think they would.

Now, has the Navy had any experience of a real serious character where homes have been subject to sound fatigue?

Mr. REKOS. Not to my knowledge, sir.

The CHAIRMAN. You have experienced broken windows and things of that sort, but there has been no claims made to the Navy of metal fatigue to homes or fatigue to timbers or things of that sort in the home?

Mr. REKOS. Not to my knowledge, sir.

The CHAIRMAN. Any further questions by any member of the committee?

Mr. MOELLER. I just wanted to ask, Doctor, is there any relationship between atmospheric conditions and these noises, to make them more intense at certain times? That is question No. 1.

No. 2: Some of the recent air catastrophies that we have had, could atmospheric conditions and this noise issue have in any way been involved to cause these unexplainable tragedies?

Dr. TRUMBULL. Sir, in answer to the first question, certainly the atmospheric conditions do contribute to the type of noise you have; the manner in which noise is transmitted would depend upon the nature of the atmosphere.

I am in no position to make an evaluative judgment on aircraft failures or recent accidents. I read newspaper articles and summations of that type, but I would not venture any guess at all.

Mr. SISK. Mr. Chairman, could I inquire on one thing?

The CHAIRMAN. Mr. Sisk; yes.

Mr. SISK. As I understood his answer to your questions, the type of noise which carries a more or less heavy or vibrating type of noise does the greater damage rather than a shrill or high-pitched or piercing type of noise. Did I understand that to be your answer to the chairman's question?

The thing that gets so intolerable to human beings is this high piercing or shrieking type of sound which sometimes you get in jet engines which gets to be very high pitched, and yet on the other hand, there are types of sounds—for example, such as a gasket which has blown, where it is impossible to talk but the ground literally shakes, and yet it is a very low pitched noise. I mean it is a muffled type of noise, although a tremendous noise.

Now, did I understand your answers to the chairman to be that that lower pitched type created the damage much more so than the high-pitched noise?

Is that true or not?

Mr. REKOS. In the past this has been our experience. However, we have experienced fatigue failures with high-frequency noise. However, with the introduction of the turbofan, we do come up with this high, shrill noise due to the inlet and this is going to require some more work as far as reducing that particular frequency associated with inlets of turbofan engines.

Mr. SISK. From the nerve angle, that is much harder on people, is it not, than the noise of the low-pitch type, which isn't as irritating. That would be my interpretation of it.

The CHAIRMAN. Mr. Fulton?

Mr. FULTON. The Navy has had a history of loss of personnel hearing due to gunfire, explosions and various other exposures to high-intensity noise. Could you put in the record something of the history that you have had on that?

Secondly, I would like to know what the cost of compensation for loss of hearing through traumatic causes has been in the services. Maybe you would have to get that from the Veterans' Administration. You see, there is a cost to this. I was talking to a Navy doctor at Bethesda Naval Hospital recently, and he said the Navy has treated many people from World War II that have a certain range or a notch of hearing loss through gunfire or through carrier aviation.

We have always talked here of full-scale hearing loss, as the effect of sounds. Could you put something in the record to show how it may affect certain levels of hearing?

Dr. TRUMBULL. We will be happy to, sir.

Mr. FULTON. You see, I think we need detail on what the effect is on the average individual within limited hearing ranges. Because I could see very well that on guns you would get a certain hearing loss at a specific frequency band.

(The information requested is as follows:)

DEPARTMENT OF THE NAVY,
OFFICE OF THE SECRETARY,
Washington, D.C., August 30, 1960.

Memorandum to: Capt. H. J. Silberstein, USN, special technical staff consultant, House Science and Astronautics Committee, House of Representatives, Washington, D.C.

Subject: Additional information to be inserted in the record in connection with Navy testimony at the hearings by the House Science and Astronautics Committee on Aircraft and Missile Noise, August 24, 1960.

Enclosures: (1) Statistical data on invalidings from the Service for Deafness, BUMED–47 of August 29, 1960.
(2) "The Nature of Typical Hearing Losses in U.S. Navy Personnel," Cmdr. Taylor, Jr., MC, USN, August 29, 1960.

1. As requested by Mr. Fulton, Republican, of Pennsylvania, information is furnished as enclosures (1) and (2), giving the experience of the Navy in discharges for loss of hearing due to acoustic trauma at present and during World War II, together with the typical type of hearing losses incurred, respectively.

2. Mr. Knapp, telephone code 118, extension 3082, of the Legislative Service of the Veterans' Administration, has been requested to furnish direct to the committee information concerning the cost of compensation for loss of hearing through traumatic causes as requested by Mr. Fulton for the record of this hearing.* The Navy does not have this type of information available.

C. E. RICE, Jr.,
Captain, USN, Director, Congressional Investigation Division.

TABLE 1.—*Invalidings from the service for deafness due to heavy firing, Navy and Marine Corps personnel, 1939–48*

Year	Number	Average annual rate per 100,000
1939–41	8	1.1
1942–45	350	3.5
1946	49	3.7
1947–48	16	1.5

NOTE.—Diagnostic statistical classification changed in 1949, therefore precluding continuous series through 1959.

TABLE 2.—*Invalidings from the service for deafness due to degeneration of acoustic nerve and deafness due to acoustic trauma, Navy and Marine Corps personnel, 1949–59*

Year	Number	Average annual rate per 100,000
1949	8	1.5
1950–53	336	9.4
1954–56	260	9.5
1957–59	250	9.8

Source: NAVMED–F Individual Statistical Report of Patient.

THE NATURE OF TYPICAL HEARING LOSSES IN U.S. NAVY PERSONNEL

The experiences of the Navy have shown, as with other investigators, that in any evaluation of acoustic trauma the pattern of hearing loss is essentially the same. At first this consists of a decrease in hearing at 4,000 c.p.s., whether the loss be due to gunfire, airplane-engine noise, or other type of acoustic trauma. If the acoustic trauma continues or is repeated, the loss at 4,000 c.p.s. becomes very severe and the hearing loss extends into the upper and lower ranges as well. However, in the early stages this hearing loss is often reversible if the individual is removed from the noise source. There is marked individual variation in sensi-

* The information when received will be found in the committee files.

tivity to acoustic trauma. Some individuals will show a hearing loss with a minimum of acoustic trauma.

There is no appreciable disability from the hearing loss unless it extends into the 2,000 c.p.s. range. This is because voice communication is primarily in this area. Therefore, personnel with a loss in the 4,000 band may be unaware of any hearing difficulty until tested by the audiometer.

Comdr. G. W. TAYLOR, Jr., MC, USN,
EENT Service, U.S. Naval Hospital, National Naval Medical Center, Bethesda, Md.

Mr. FULTON. One other point I wanted to ask. Have you made any checks in the services to find people who are more resistant or more adaptable to high decibel sounds so that you aren't sending in people whose hearing is easily destructed? For example, have you tried any preventive steps on injury through sounds?

That is a selectivity of personnel in the services so that you then match selectivity and sound adaptability with individuals of that kind and keep out the others who are, for example, as Mr. Sisk says, some people who can very little tolerate these high, shrieking noises, or it might be the reverse, the low pulsating, vibrating sound?

Dr. TRUMBULL. This has taken a number of turns, Mr. Fulton, in trying to evaluate how we can best use people in this way. There has been the concept of the sensitive ear for a long time. How do we get at it and can you predict whether a person who might be sensitive to a hearing test or a particular frequency in a test, how that same ear would actually operate later on in some situation.

We actually went so far in dealing with this, at Pensacola, to start a program aimed at using deaf people on the carriers. This represents just one more attempt. We found individuals then whose hearing already had been destroyed for which we would not be responsible. You find when you do this, the problems of communication and a number of other problems are such that, in addition to which the noises had reached such a level you had these extra auditory effects, this is not feasible.

Generally, just shaking of the whole system, feeling of nausea, dizziness, and it is true none of these individuals were subjected to this for a long enough period of time to run into this adaptation of which you were speaking a moment ago, but it just proved to be so unfeasible that we gave that up and went back again to just protecting the ears.

The CHAIRMAN. So, in effect, what you are saying is the additional effects of sound even upon a deaf person could be very serious if prolonged and of sufficient intensity?

Dr. TRUMBULL. Yes, sir.

The CHAIRMAN. Do you agree with the witnesses that testified yesterday that the noises on the jets are largely not noises of the operation of the jets but are noises outside of the jets? Do I get my meaning over to you?

Dr. TRUMBULL. Yes, sir. If I may, I would rather refer this to Mr. Rekos who knows the powerplant aspects.

The CHAIRMAN. Mr. Rekos.

Mr. REKOS. Yes, sir; it is generated primarily outside the jets, somewhere in the vicinity of 5 or 10 tailpipe diameters downstream.

The CHAIRMAN. That makes it more difficult to control; doesn't it?

Mr. REKOS. Yes, sir.

The CHAIRMAN. Now, one more point I want to clear up. You referred to the fact that there would be damage to surrounding property by these noises from airports.

In reference to that, explain just how close that noise would have to originate in order to cause damage to a home or something of that sort; or how continuous it would have to be?

Mr. REKOS. What we were referring to before, you would have to have the jet relatively close to the property. As far as feet or miles are concerned, we don't have those figures at hand.

The CHAIRMAN. It would have to be very close, though, and of long continued duration?

Mr. REKOS. Yes, sir; it would have to be relatively close.

The CHAIRMAN. You have no claims pending of that character?

Mr. REKOS. Not as far as I know.

Mr. SISK. If I could pursue that just a little further, I happen to know of some longstanding complaints at a bomber base, Air Force, not the Navy. There is a B–52 base in my district. We finally solved the situation by the Air Force actually taking the house over.

I went into a home over which B–52's were taking off and practicing landings, and I mean to tell you the furniture actually gets up and walks around.

Now, the home was not sitting close to the airport boundary. The home actually was a mile or so from the base, but it was right under the flight pattern and in these practice takeoffs and landings, boy, I am telling you, if it wouldn't have wrecked that home—I believe it would come close to it.

Talk about vibration and things bouncing around, I was actually there and experienced it a few times. In fact, finally the Air Force bought the home and moved it out.

But I tell you, this problem is a lot more than just the proximity of a home to an airport. We have got this problem even when these planes are airborne.

Don't you agree?

Mr. REKOS. Yes, sir; I agree with you.

I think Lieutenant Commander Dagg did point out that these commanders at the naval air stations do attempt to pick out the flight path so it will go over the least number of homes.

Mr. SISK. Of course, that is pretty difficult when you have various wind directions and after all we can't control the direction the wind is going to be blowing.

Mr. REKOS. Yes, sir.

The CHAIRMAN. If there are no further questions we want to thank these gentlemen from the Navy for their help to this committee on this very vexing problem.

(The prepared statement of Dr. Trumbull is as follows:)

STATEMENT BY DR. RICHARD TRUMBULL, HEAD, PHYSIOLOGICAL PSYCHOLOGY BRANCH, OFFICE OF NAVAL RESEARCH ON NAVY PROGRAMS RELATED TO AIRCRAFT AND MISSILE NOISE

AIRCRAFT AND MISSILE NOISE IN THE NAVY: A REVIEW

The problem of aircraft noise has confronted the Navy from an early date primarily due to the fact that an aircraft carrier deck offers no other place to go. Our operational confinement, then, made us more conscious of its annoyance at a time when that term adequately represented the problem. The increase in power of aircraft engines and the advent of jet aircraft, have increased by an order of magnitude almost all of the problems which noise presents.

It is necessary to consider our problem in this light because, in the main, our approach was to do more of what we had been doing rather than initiate something totally new. Our efforts toward the latter, however, have accelerated some rather unique studies.

Flight in open-cockpit aircraft was known to produce a tonal island or "aviator's notch" with a characteristic loss of hearing acuity within a relatively narrow band. History does not record whether the first helmet was introduced to protect the ear from this damage or to cover the head, but its continued development has increased the emphasis upon the protection of hearing and facilitation of communication. Further, early carrier-deck procedures limited personnel in launch areas possibly as much from consideration of accident potential as of their hearing.

Location of airstrips and warming-up areas at naval air stations in relation to housing or, the reverse, location of new housing in relation to operational requirements, might have originated in deference to accidents as much as to noise. All of these aspects, to which this report is now addressed, had early beginnings and multiple reasons for those beginnings. The same multiple reasons for action still exist today in the form of safety, protection, power, comfort, and property rights. Attainment of the ideal, in any given situation, must be foregone in some form of compromise. The objective of those concerned with each aspect of noise is to assure that the compromise is always in their favor. The best example of this came from the source of our problem—the power system. Indeed, at one time we were told and were almost convinced that this was something that we would have to learn to live with if the powerplants were to become bigger or if military power and booster sources were required for our operational needs. Fortunately, our concern for personnel already had reached a point where this was unacceptable. We shall begin, then, with the Navy's approach to this problem from the personnel aspect This will be followed by discussions of noise control and community relations.

Personnel: The first reference to a research approach is of a Bureau of Medicine and Surgery survey in 1952, measuring noise levels at various places on the flight deck of one of the larger carriers, the first to carry jet aircraft. Intensities that regularly reached 130 to 135 decibels (F4U–4, AD–4, and F2H–2) were associated with hearing loss in flight personnel in the range above 1,000 c.p.s. a hearing loss that impairs voice communications (14).

Recognizing that this situation was to become worse, the National Research Council Committee on Hearing recommended that "the Navy * * * appoint a small group to gather information on the present knowledge of, and present work in progress on, the subject of acoustic trauma, and in the light of this information to suggest the next steps to be taken in relation to the urgent practical problems arising from high-intensity noise. It is assumed that this group will establish liaison with the Air Force and appropriate industries, and consider the possibilities of combined or cooperative effort in relation to these problems." (29) This Noise Survey Team, supported by an Office of Naval Research contract with the Psycho-Acoustic Laboratory of Harvard University, visited Naval and Air Force installations, academic institutions, and aircraft industrial concerns preliminary to observing operations abroad a carrier.

Despite launching frequencies as high as 20 in one 25-minute period, in levels of 124–132 decibels at 35 feet, the earlier study had reported that "only one man was observed to cover his ears with his hands during runup and takeoff, and no ear protection was observed in use during any of the operations." (14) The Noise Survey Team concluded that measuring equipment would need some improvement for exact calibration of afterburner intensities which were registering above 140 decibels. It also was evident that such levels as could be anticipated in the near future would result in nonauditory effects as well. The magnitude of the problem now became apparent as did the immediate need for some interdisciplinary committee to cope with it. At the recommendation of the Committee on Medical Sciences of the Research and Development Board of the Department of Defense and the endorsement of the National Research Council Committee on Hearing, a group of civilian and military experts organized the Armed Forces-National Research Council Committee on Hearing and Bio-Acoustics (CHABA) at a meeting on December 15, 1952.

This Committee with Dr. Hallowell Davis as executive secretary followed the format of one previously established on vision and both were to function under the contract program of the Office of Naval Research, Physiological Psychology Branch. Membership was to be composed of a balanced military and civilian representation with liaison members appointed by other interested Government agencies. Areas of interest were (1) the effects and control of noise, (2) auditory

discrimination, (3) speech communication, (4) fundamentals of hearing, and (5) auditory standards.

One of the first working groups of this Committee was on biological effects of noise, exploratory (Benox). It conducted a study at Patuxent River and on board the U.S.S. *Coral Sea* to check sound levels of twin-jet aircraft and the protection afforded by current muffs and earplugs. Afterburner levels of as high as 155 decibels overall were found on initial lighting with sustained levels about 152 decibels. Exposure at positions occupied by subjects (in normal crew positions) ranged from 131 to 150 decibels. Afterburners were on 15 seconds at 45-second intervals, 10 times on the first day and 15 times on the second. No significant hearing loss was found in those wearing any of the three muffs at 150 decibels or the V51–R plugs (currently used in the Navy) alone or in combination with muffs at 150 decibels. Recommendations were made on muff and/or plug wearing for crewmen in various positions with reference to noise source, zoning of decks, procedures for engine testing and operations and for an audiometric monitoring of personnel. The presence of these test helmets attested to the early concern and 1953 saw the first Bureau of Aeronautics directives on helmets, plugs, and two-way communication development.

The multidisciplinary aspects of the problem were brought closer to the public through the December 1, 1953, Benox report (3) which summarized the experience to that date. Nine recommendations were made for immediate action:

(1) Education and selling of earplug use by personnel.
(2) Improve availability of ear defenders.
(3) Evaluate and, where indicated, change operational procedures in recognition of personnel hazard.
(4) Establish training courses for communication in noise.
(5) Instruction of personnel in high noise zones on all hazardous aspects of their job.
(6) With visual communication and contact at a premium in such areas, special attention should be given to its protection.
(7) Screen out any men with past medical history of epilepsy.
(8) Where possible, establish routine audiometric checks.
(9) Establish laboratories where high-intensity noise can be generated and its effects scientifically studied.

Recommendation (9) was further delineated into 19 suggested areas of research on tissue, system, and performance alteration under noise. Research had been underway on many of these items in laboratories and under the Office of Naval Research contract program. A task with the Central Institute of the Deaf now broadened into "the effects of intense sounds upon the ear in terms of injury and extent of hearing losses, and the development of techniques and devices for several types of acoustic measurement." Already, experience had demonstrated that much was needed by way of equipment for noise level measurement and audiometric baselines and monitoring. The year 1953 was to see CHABA involved in these aspects as well as the broader requirement for international standards for audiometry. (Here was a graphic illustration of the mutual assistance given and received by such military—civilian coordination. While the military had much to gain from civilian counsel, those civilians involved in major advances in their professional fields found the military a large enough user to provide a test run for or initiate action which must be reflected ultimately in industry and other civilian structures.) Relevant data continued to be realized from the contract research program. From the Psycho-Acoustic Laboratory at Harvard came new developments in high-attenuation earphones and earplugs. Research on physiological and psychological effects of high-intensity noise on man by Neff of the University of Chicago and on vestibular and postural effects by Ades of Emory University was accelerated. Materials for speech audiometry had progressed to the point of application in various hospitals and military installations.

The Bureau of Aeronautics issued its Instruction 3923.1 on November 23, 1953, allocating responsibilities for an aircraft noise control program. This included responsibilities for protection of personnel and improvement of communications under noise conditions. Here, too, was early recognition of the guided missile as the next noise source. Its laboratories now advanced their work on transmitting loops around the deck, two-way radio communications.

A new program was undertaken by the Bureau of Medicine and Surgery and the Office of Naval Research at the School of Aviation Medicine, Pensacola. A fixed unit and a mobile unit for measuring audiometric performance of personnel routinely were established. The mobile unit, constructed on a trailer bed, could be placed aboard any carrier for studies of noise sources, protective devices, and

impairment with a minimum of time delay between exposure and testing. In addition, Halstead of the University of Chicago began his work on measurement of high level noise and stress effects upon higher brain function, an attempt to understand psychomotor involvement. Also on the performance side, a contract with Ohio State brought personnel into Pensacola for evaluation of equipment and research on improvement of voice communications. (6)

Research data were being developed rapidly so the classic 1950 report on "The Effects of Noise on Man" by Kryter (19) now could be documented across many disciplines in Loring's "Selected Bibliography on the Effects of High Intensity Noise on Man" (1954) (23). Concern was shown for "Hearing Losses of Aircraft Repair Ship Personnel" as the Navy Electronics Laboratory strengthened its capability in sound measurement and evaluation. (40) The Naval Medical Research Laboratory at New London pursued "Recovery Curves and Equinoxious Exposures in Reversible Auditory Fatigue Following Stimulation up to 140 DB" (15). In this wise, contract programs and inhouse research talents were now available. Communications continued to pose problems as reflected by Pensacola's 1954 reports, "Flight Deck Noise-Exclusion Personnel Helmet (FDPH) Evaluation" (38) and "Speech Reception and Temporary Hearing Loss as a Function of Exposure to High-Level Noise" (32).

Concepts of ear protection were changing (47, 45) and much of this period found all the laboratories involved in evaluation of earplugs, muffs, and helmets (16, 33, 34, 42). First, however, there was a need for developing an accurate method for such measurement. Both contractors and laboratory personnel contributed to this effort (41, 46). On the broader scale, the Committee on Hearing and Bio-Acoustics issued its reports on "High Intensity Noise and Military Operations" (11) and "Recommendations for Air Base Noise Surveys" (9).

During 1955, a CHABA working group contributed its recommendations on a "Standard Method for the Measurement of the Real-Ear Attenuation of Ear Protectors" (17). Studies of high-intensity exposures continued with reports on "Electric Responses of the Guinea Pig Ear to High Audio Frequencies" (27), "Patterns of Injury Produced by Overstimulation of the Ear" (43) and "The Control of Sound Transmission by the Middle Ear Muscles" (44). "Psychophysical Effects of Noise" received another evaluation (26) and a new means for control of flight deck personnel was sought as work advanced on "The Utilization of Cutaneous Reception for Communication" (13).

The year 1956 saw continuation of most of the developments above. The mobile audiometric laboratory (8) was finished and placed aboard a carrier where audiometric data were collected during actual flight operations. These data did not establish the presence of significant hearing losses among the naval personnel taking part in the test. However, the investigators cautioned that increase in noise fields above then present levels or continued exposure even at those levels might result in permanent auditory damage.

Significant accomplishments were achieved in the evaluation of nonauditory effects. Utilizing deaf subjects, so as to avoid the possibility of damage to a functional hearing system, the noise level at which hemorrhage of the middle ear might be expected was determined (2) as well as information concerning the visual disturbances which arise in a high-intensity sound field.

In the course of experimentation concerning diagnostic indices for the detection and localization of brain damage following trauma, high-intensity noise exposure, or disease, a battery of tests was developed and validated against neuropsychiatric examination. In the meantime, the Bureau of Medicine and Surgery had issued its directive on hearing conservation (1955), a program for protection of its civilian employees in areas of high noise exposure as well as for its aviation personnel.

The need for better measurements upon which to make relevant decisions demanded improvements in every aspect of this multidisciplinary problem. (12) Most of the third annual meeting of CHABA had been devoted to a review of testing of hearing in the armed services, types of audiometry employed and their rationale, and the new problems facing the services and industry. Its report on "Monitoring Audiometry and the Medical Disposition of Cases of Hearing Loss" (18) provided major guidelines to the armed services and other faced with these problems. Instrumentation had been aided by an "Evaluation of High Intensity Microphones for High Intensity Noise Instrumentation" by the Material Laboratory at the New York Naval Shipyard (20). Other efforts there produced "The Characteristics of Noise Canceling Microphones—A Survey" (21) and "Methods of Specifying the Noise Canceling Characteristics of Noise Canceling Microphones" (22).

Nineteen hundred and fifty-seven was a productive year for CHABA as procedures for audiometry in service selection, monitoring of hearing (39), establishment of hearing loss and bases for compensation were developed. Criteria for hazardous exposure of personnel on flight decks, hanger decks, around test stands and other hazardous areas were established. Scripts for training of, and instructional material for, military personnel were written and incorporated into three films on this problem. Standards for measuring noise around airfields and neighboring communities were set for determining location of new housing and working areas. A CHABA working group completed a valuable review and critical appraisal of current instrumentation and equipment for the measurement and generation of high-intensity noise, including both continuous jet noise and blast-type noise from rockets and gunfire (5).

Experience with flight deck crews and the continued tendency to overlook or deliberately refuse use of protective devices available resulted in an evaluation of "Ear Protection Effectiveness Versus Comfort." (48)

The natural protective measures available to man were explored at the Air Crew Equipment Laboratory in "Effects of Jet Engine Afterburner Noise: Objective Measurement of the Auditory Reflex in Man" (25). The School of Aviation Medicine continued its work on the nonauditory effects as found in vision, with work on flicker fusion (significant decrease) (24) and nystagmus (increase) (1). Testing of protective equipment continued (35, 36, 37).

The October meeting of CHABA clearly reflected the areas of concern and interest which had developed over the years. There was a new term but an old problem in the working group report on "Bio-Acoustic Aspects of Rockets, Missiles, and Space Travel." Noise can be found in many places. A later session on "Aircraft Noise, Annoyance and Community Responses" served as a reminder that an earlier problem still demanded solution. Previous exposure to impulse noise, that of blast and small arms fire, had helped confuse the picture in the trailer studies on board carriers. (10) It now began to receive more attention on its own after being overlooked during concern about jets and missiles. This, too, is a Navy problem and the same care in initial audiometry and monitoring now will be exercised with marines and others whose daily operations result in such exposures. A vital equipment need was satisfied through the trailer experience and development of a noise-cumulator, a device for providing accurate information on intensities and frequencies to which personnel are subjected during performance of their routine tasks. (7) These baseline data and those in audiometry are the foundations for determining the actual influence of noise upon hearing. Too, it gives us a picture of the frequencies against which protection must be afforded. Under current evaluation is an earplug which does appear to provide much better protection in the lower frequencies where others had proven to be wanting. Pensacola reported that these plugs give better attenuation than any device they had tested especially below 500 cycles per second frequency. The relative attenuation is remarkably flat and reaches 30 decibels in the lower range. The U.S. Navy Electronics Laboratory had completed its work and could provide "Anatomical and Physiological Criteria Governing the Design of the Noise Attenuating Radio Communications Helmet" (28). These helmets are now getting into the fleet as rapidly as they become available, satisfying needs for both better communications and increased safety.

The problems of audiometry had occupied the Bureau of Medicine and Surgery over the years. Establishing hearing conservation programs in the absence of agreement as to what constituted a true measure of threshold, functional hearing or other acceptable criterion posed this as the primary problem. This Bureau had underwritten development of various audiometers to meet its many needs from selection screening through monitoring to an exact clinical testing. Individual audiometers and group audiometers, automatic and nonautomatic were but some of the variables to consider. Fortunately, a CHABA working group has provided guidance for those faced with procurement decisions in its report "The Evaluation of Audiometers" (4) which sets standards and compares many of those now available. Success with the acoustic trailer on board carriers helped strengthen requirements for acoustic booths or treated spaces on board for audiometric purposes. Today, both booths and treated rooms are to be found on carriers in operation and at all naval air stations. This course of events is moving rapidly. A group audiometer is presently having an evaluation run on a carrier. Smaller, individual audiometers for screening and monitoring have proven to be of value. These developments are necessary for the proper execution of the Bureau of Medicine and Surgery hearing conservation program as outlined in BUMED Instruction 6260.6A of January 1959. This program is now recommended for all personnel exposed to noise levels of 85 decibels and is mandatory for those in areas of over 95

decibels. It should be expected that inauguration of improved screening and monitoring techniques will result in: (1) reduction of personnel available to service, and (2) removal or survey of some now in service. However, once this initial period is over, we shall enjoy improved selection, better protection and a reduction in disabilities arising from a noisier military world.

Noise control: While protection of personnel is the primary function of the Bureau of Medicine and Surgery, early support for this mission had been contributed by the Bureau of Aeronautics' Instruction 3923.1 of 1953, allocating responsibilities concerning the aircraft noise control program. The same mutual assistance is evident in the industrial hygiene and other hearing conservation efforts of the former Bureau (1955–59) where recommendations are found on treatment and design of hazardous areas. Sketching the Navy's progress in the area of suppressors, shields, acoustic treatment, and noise-level reduction finds other areas of mutual concern—that with industry. While much had to be done directly with personnel problems, those of noise at source and intermediate buffers could best be handled through writing of specifications and close liaison with aircraft and powerplant producers. BUAER Instruction 3923.1 had assigned responsibilities for noise measurement, reduction, and studies on effects upon personnel and structures. In the meantime, the Bureau of Ships had faced the problem of maintaining communications in the island structure. In 1953, they had set up a test program at the Naval Air Test Center to evaluate the soundproofing of a new design island structure for aircraft carriers. A mockup of a portion of the proposed CVA–59 island structure and jet aircraft were used under simulated carrier conditions to determine the acoustic requirements of the island structure. BUSHIPS then participated in the U.S.S. *Coral Sea* surveys indicated earlier. A conference was held by BUSHIPS to formulate a comprehensive test program for conducting the noise level-human efficiency survey. Objectives were to (1) determine safety regulations for afterburner turnup on catapults, (2) evaluate personnel protection devices, and (3) measure noise intensities to serve as a basis for acoustic shipboard modification.

The Naval Air Test Center initiated its program to determine the noise levels surrounding the F3H–1 and F7U–3 aircraft with afterburners operating and to determine the effect of these noise levels on operating personnel. These actions had been undertaken prior to the BUAER allocation of responsibility in the instruction in 1953. The Ship Installation Division was assigned cognizance of the following:

(1) Carrier-deck equipment assigned to absorb, focus, dissipate, or otherwise attenuate noise levels of carriers.

(2) Noise-measurement techniques and standards; liaison with the Bureau of Ships.

In 1954 the need for long-term audiometric surveys had been established. Requirements for acoustically insulated compartments providing ambient noise level below 50 decibels, capable of accommodating 8 to 10 individuals for group audiometry were being met in all classes of carriers. For guidance, the Bureau of Ships had issued its general specifications for ships with section S1–10 on noise, shock, and vibration.

As early as September 1955, the Powerplant Division of the present Bureau of Naval Weapons had established a project at the Aeronautical Engine Laboratory for the purpose of designing, fabricating, and testing several types of portable jet-exhaust silencers suitable for ground use with an afterburner jet engine.

The Aeronautical Engine Laboratory at Philadelphia is considered unique in that it makes use of a 25,000-pound-thrust table mounted on a 40-millimeter quad gunmount permitting rotation of a test engine in an arc of 270° past microphone positions. Engines up to 25,000 pounds of thrust can be tested on the rotating stand. Prior to this development, accurate noise surveys were hampered by calibration changes made necessary when microphones were moved about.

Five basic methods of reducing jet-engine noise have been considered by the Navy. Any practical solution will depend on one or more of the following principles:

(1) Atmospheric attenuation: Absorb the noise by increasing the distance between the aircraft and the receiver. Noise levels are reduced approximately 6 decibels when the distance from the noise source is doubled.

(2) Source reduction: Decrease the total sound power radiated by the source.

(3) Directivity: Modify the directional characteristics of the source.

(4) Frequency shift: Alter the frequency spectrum by changing or shifting the disturbing low-frequency noise to the less disturbing and more readily attenuated higher frequencies.

(5) Cancellation: Cancel the noise by superimposing another noise source 180° out of phase with the original jet source. This method is by far the most difficult to accomplish since noise is a random condition both in frequency and loudness.

At present the most practical method of noise reduction is by atmospheric attenuation—increasing the distance between the source and the receiver.

Since a high percentage of the noise energy produced by a jet engine occurs in an area 5- to 10-tailpipe diameters in length downstream of the tailpipe, most of the mechanical devices being considered for inflight noise suppressors have been designed to mix rapidly the highly turbulent, high temperature exhaust gas stream with the cool ambient air surrounding the jet. Results have shown that these devices are capable of suppressing noise but not without imposing drag, weight, and engine performance penalties. Decreasing jet velocity is another method of reducing noise at the source. However, today's engine, designed to provide the maximum requirements of the military, cannot operate efficiently at lower jet velocities.

In 1955 the Soundrive Engine Co. was awarded a contract to investigate the nature and possible suppression of turbojet engine noise by the internal application of acoustic dampers. This method of noise suppression proved to be unsatisfactory. The masking effect of externally generated noise precluded any significant noise reduction by internal acoustic treatment. However, the contractor did demonstrate the feasibility of suppressing the discrete frequency noise associated with inlets and compressors of jet engines. The internal acoustic treatment techniques used are quite similar to those being put into actual practice on turbofan installations.

In April of 1956, a project was established at the Naval Air Test Center to provide for the measurement of the engine noise profiles of then current as well as future naval jet aircraft. Such information on noise levels, proceeding new aircraft into operational use, would keep medical corps and other personnel on guard and provide a basis for changes in operational procedures where indicated. In May, CHABA issued its memorandum report on "Evaluation of Methods for Reducing Noise from Jet Engines in Flight" (30). In 1958, this project was backed by an extension of that with the Aeronautical Engine Laboratory for analyses of spectra from engines as well as investigation, test, and evaluation of new and novel methods of jet engine noise suppression. The Committee on Hearing and Bio-Acoustics issued its third report on suppression, "Estimate of Performance of Jet Engine Noise Suppressors for Flight Use" (31).

Meanwhile, a contract had been awarded the research division, Curtiss-Wright Corp., to conduct analytical and experimental research utilizing small-scale model tests to obtain design parameters and performance analysis for inlet and exhaust noise suppressors. The inlet noise suppression problem was approached utilizing the resonator principle. In theory, this type of inlet suppressor will attenuate the high frequency inlet noise inherent with turbojet compressors without appreciably affecting the overall sound pressure level. Tests conducted under this contract revealed that the low resonant frequency (480 c.p.s.) resonators attenuated the inlet noise 7 to 10 decibels at the resonant frequency, but the high resonant frequency (1,540 c.p.s.) resonators increased the inlet noise level at some frequencies. The exhaust noise suppression portions of this effort resulted in the development and model tests of concentric nozzle configurations which exhibited a maximum attenuation capability of approximately 10 decibels. However, the thrust losses associated with the use of this suppressor were considered prohibitive.

The problem of providing adequate noise suppression with little or no penalty in performance of Navy combat aircraft has been extremely difficult especially with afterburning engines. All available noise suppression work conducted by both industry and other Government agencies has been and still is continuously reviewed for possible application to naval aircraft. However, the minimum acceptable limits of 30 decibels of suppression at a penalty of no greater than 1 percent in performance does not appear to be in reach in the near future. The use of the turbofan engine in the new long-range missile fighter (Missileer) holds some promise for limited relief from noise since the turbofan engine with its large mass of low-temperature, low-velocity fan air lends itself to acoustical treatment. Noise reductions up to about 17 decibels may be achieved with the turbofan engine.

In view of the difficulty in providing adequate in-flight suppressors for Navy combat aircraft and in view of the extensive effort by industry in developing suppressors for commercial use, the Navy has decided to go back to the books

in the hope of finding a key to the suppression secret. It is hoped that by going back to the laboratory to investigate the fundamental factors affecting the generation of noise such as temperature, velocity, pressure, turbulence, etc., we may obtain a clearer understanding of the exact nature of noise and by doing this basic research we may be able to develop new techniques for solving the noise problem.

Thus, in 1959, this new direction took effect through a contract with the General Electric Co. to conduct experimental tests and research to determine the basic mechanisms of the turbulence-shear interaction as a factor affecting the generation of jet engine noise. It is not expected that this type of work will bear fruit in the immediate future. However, it is firmly believed that as we continue to learn more about noise, we will eventually find the technique wherein we will be able to provide the necessary noise suppression required for Navy aircraft.

The requirement that an in-flight noise suppressor be extremely lightweight severely limits the development of satisfactory suppressors. However, in the area of ground-type noise suppressors, where weight is not a critical parameter, it appears that a solution to the problem of reducing noise resulting from ground operations of turbojet engines in an airframe or on a portable test stand is in sight.

Ground-type suppressors rely principally upon the reduction of exhaust jet velocity (noise varies approximately with exhaust velocity to the eighth power) by grids, screens, etc. In February 1958 the Navy undertook an evaluation program to determine the full capability of the then commercially available ground turnup suppression devices. The Navy concurrently initiated development of optimized portable ground suppressors that could provide approximately 30 decibels of suppression plus being able to operate in an afterburning environment for 15 seconds without cooling water. Over 100 of the above units were purchased for test, evaluation, and further development at various Navy and Air Force airfields. Sufficient data were obtained from these tests to assure that the design goals for suppression were met. The most promising of these suppressors are currently being evaluated for fleet usage. The Navy in 1960 has also issued contracts to two concerns for research and development of an advance type of portable ground suppressor that acoustically treats noise generated from both the jet engine inlet and the jet engine exhaust. It is expected that approximately 45 decibels of suppression will be possible with these devices. These suppressors will be subjected to extensive tests at the Navy North Island Air Station during the period from September to December 1961. The objectives of this effort are:

(1) Reduction of near-field noise (within 50 feet of the engine) and for field noise (over 250 feet from the engine) to a level no greater than the noise generated internally of the engine itself.

(2) Increase afterburner operation without water cooling to 90 seconds.

(3) Provide a more versatile and maneuverable, portable suppressor.

The efforts to date with portable ground-type suppressors have been very encouraging. It is believed that by 1962 the Navy will be able to provide ground-type suppressors capable of 45 to 50 decibels of suppression for use on jet engines of up to 20,000 pounds of thrust. This type of performance will no doubt contribute very materially toward the eventual elimination of the noise problem associated with ground runup operations.

Missiles: The advent of missiles on cruisers posed the same types of problems as did the jet aircraft on carriers. The reflecting surfaces and limited space available for leaving the area demanded the same limitation on required personnel and barriers between the source and personnel areas. The techniques, accurate sound level meters, and personnel protective devices previously developed were available. The first evaluations of the Terrier missile found but one position exposed to over 140 decibels of noise. These studies were done with various launch positions and consideration of resulting deflection angles from deck and surrounding structure. These studies also drew upon the capabilities of the U.S. Naval Weapons Laboratory at Dahlgren, Va., where all relevant data on new missile systems will be available for guidance in the same manner as are those on new aircraft at Patuxent Naval Air Test Center. Also, as with the aircraft problem, motion pictures were made of firings with appropriate sound level recordings to familiarize crewmen with operations of these missiles.

It is true that more powerful sources will evolve and that the Pacific Missile Range will provide the Navy with exposures to the major noise sources anticipated. The same directives concerning personnel protection, suppressor development and housing location requirements have already considered these extensions. At this range, the Navy is building its launching pads for the missiles of tomorrow deep in ravines to take advantage of terrain attenuation and

central to the land mass over which the Navy will exercise control. This will not answer questions relative to misfires or postlaunch destruction but should return us to the situation where we are concerned over safety of personnel within the operational area rather than their hearing. This was where we started in aviation years ago.

Community: It is quite conceivable that the Navy had its first "community" reaction to jet noise as the 2,000 plus personnel on aircraft carriers became accustomed to night operations. That they were Navy personnel and this was the carrier group with which they worked should be borne in mind as we discuss the community at large. The second level of community with which the Navy was concerned was that of naval air stations.

To those charged with planning and zoning of military bases, jet-engine noise was but another variable to be considered in the compromising indicated in the introduction to this report. The National Resources Planning Board had provided guidelines for general zoning in its 1941 Bulletin R–56. Specific questions relative to operation of aircraft were raised in the 1952 report of the President's Airport Commission on "The Airport and Its Neighbors." Although local commands and some few offices in Washington had begun to receive complaints, many more military and civilian personnel associated with the military were made acutely aware of the problems by the 1954 annual meeting of CHABA. Here the Air Force Strategic Air Command problem was raised and discussed against a background of other known noise sources and techniques for appraising community reactions. Need for the latter has never been satisfactorily met.

Beginning early in 1955, an ad hoc committee on jet aircraft problems met for a series of meetings and in October produced a report for the information and guidance of the Assistant Secretary of the Navy (Material). This became available at the same time as the BUMED Instruction 6260.6 on hearing conservation and the Navy was ready for action. An instruction was issued by BUDOCKS on May 10, 1956, providing "Information and data to be assembled for use by acoustical engineering firms in evaluating proposed sites of family housing at Naval and Marine Corps air stations." Over 34 such surveys now have been completed by such firms for the guidance of the Bureau. BUDOCKS Instruction 11012.57 was issued in July 1956 and established the first requirements of distance between housing and aircraft launch and made recommendations for further treatment at the source, direction of sound energy, baffles, and other devices. In addition there were specifications for construction to counter noise.

Over these years, construction of stations and their runways had to be effected by additional compromises reached with the communities near which they were located. This is the third level of "community" with which the Navy concerns itself. The continued encroachment of housing from an expanding community after earlier acceptable limits have been established is a constant problem regardless of the original distance existing. County and town planning commissions now have to understand the nature of the operations at the field and assume some responsibility for such encroachment. One outstanding example of such a mutual development of benefits for community and naval air station was effected through zoning ordinance No. 240 of the county of Imperial, Calif. Here, full appreciation of aircraft operations allowed consideration of each aspect in relation to the overall problem of noise reduction. Such foresight is not always available and, since 1953, we have had a rather constant level of complaints about aircraft noise. It appears that just as community relations are producing a decrease in complaints at one station, a new station is exposing a new population. Just as the sound of one type of aircraft has become recognized and accepted, a new aircraft or new engine changes the picture. We find that complaints vary with geographical location, weather conditions, and the age, sex, and occupations of people. Thus, we are aware of so-called sensitive areas, based upon complaint frequency. CHABA has addressed itself to this problem as well and we look forward to the time we can anticipate these areas from sociometric measures and go into them prepared for the educational programs demanded. What are these programs? To date, we have employed lectures, newspaper articles, magazine articles, demonstrations, technical articles, and motion pictures. Every station has its open-house day. In all of these efforts, it is the local command which has to feel the pulse of the community and effect the best rapport.

On occasion the complaint goes above the local command to the Chief of Naval Operations. That this is not an extensive practice is evident from the fact that but 160 different individuals have used this channel in the past 3 years. The word "different" is used to indicate the major problem of the "chronic" complainer. The Chief of Naval Operations now has five such individuals, representing five different air stations, carrying on active correspondence with him.

Finally, there are the cases reaching legal involvement. The Office of General Counsel has cognizance over acquisition, custody, management, and disposition of real property. In this capacity, this Office is concerned with what constitutes a public nuisance and the interpretations of avigation easement as opposed to clearance or obstruction easement. The Office of the Judge Advocate General has primary responsibility for those operations peculiar to the military and decisions relative to what constitutes negligence in the operation of Navy aircraft. It is obvious that community reactions concerning these offices will be few in number and beyond the scope of noise as discussed here.

Conclusion: The Navy has, within its own structure, allocation of responsibility for dealing with every aspect of the man-noise problem. Competencies within bureaus are complemented by contracts with development firms, educational and basic research resources, and their own laboratory structures. The early and mutual recognition of these problems by the services has led to an outstanding exchange of information where unusual competence on the part of one has been accepted to allow concentration upon some other aspect. Certainly, from here on, our sophistication should keep ahead of the higher levels expected from new missiles to the point that judicious location of launching pads, zoning of surrounding areas, and protection of personnel will result in no major increment of noise for man in any of the three Navy community complexes.

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The CHAIRMAN. Now, we have as the next witness this morning, Dr. H. O. Parrack, Coordinator of Noise and Vibration Control, from Wright Air Development Center, Dayton, Ohio.

Perhaps Mr. Sisk and other members of the committee would want to ask him about the experience of the Air Force in the operation of high-speed craft around their bases.

So, Doctor, if you will have a seat, sir, we will be happy to hear from you. Do you have a prepared statement?

Dr. PARRACK. I have a brief prepared statement that I would like to read parts of.

The CHAIRMAN. Proceed with your statement.

STATEMENT OF DR. HORACE O. PARRACK,[7] COORDINATOR OF NOISE AND VIBRATION CONTROL, WRIGHT AIR DEVELOPMENT DIVISION, WRIGHT-PATTERSON AIR FORCE BASE, DAYTON, OHIO

Dr. PARRACK. Mr. Chairman and members of the committee, it is a pleasure to appear before you this morning to present the Air Force position relative to the problems of sound associated with our aircraft, missiles, and rockets.

I would like to reiterate in a sense the definition that was given yesterday. These sounds that are produced by the equipment, the sound waves, are noise. We will refer to this as acoustic noise whenever these sounds interfere with something a man desires to do.

[7] Horace O. Parrack, Technical Coordinator, R. & D. Technical Areas, Noise and Vibration, was born in Terra Alta, West Virginia, September 16, 1905. He completed the county elementary schools in 1921 and graduated from Terra Alta High School in 1924. Following a summer's special training, he taught in the Preston County Elementary Schools during the school year 1924–25. In 1925 he entered the University of the State of West Virginia at Morgantown, West Virginia, and received the A.B. Degree in 1929 in the field of Zoology.

In September 1929 he went to Columbia University in the City of New York where he served as an instructor in the Department of Zoology and, at the same time, continued his studies as a graduate student in this field. In 1931 he transferred to the Physiology Department of the College of Physicians and Surgeons, Columbia University, to continue his graduate studies in the field of Human Physiology. During

The sounds that we have from the devices that we talk about, aircraft, missiles, rocket engines, are strong enough to cause damage to parts of the human body and to certain mechanical structures.

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the school year 1931–32, he held a full time Research Fellowship in Physiology and received the M.A. Degree in Human Physiology in 1932.

Dr. Parrack continued his graduate studies at the College of Physicians and Surgeons in the field of Physiology while, at the same time, assuming responsibility for the operation of the Teaching Laboratory in Human Physiology, used in the training of medical and dental students. Continuing this combined activity of teaching and studying, Dr. Parrack completed work for the Ph. D. in Human Physiology in 1939. The Degree was granted by Columbia University's Faculty of Pure and Applied Sciences in 1940. His work for the Doctorate Degree was in the field of Neuro-Physiology.

In the fall of 1939 Dr. Parrack went to the Harvard Medical School in Boston, Massachusetts to continue postgraduate studies as the Porter Fellow of the American Physiological Society. This postgraduate work was also primarily in the field of Neuro-Physiology. During this period, working with other graduate and postgraduate students, he became interested in hearing and the effects of sound on the human ear and, subsequently, on the human nervous system.

In September 1940, Dr. Parrack continued his graduate studies in combination with a teaching position as an Austin Teaching Fellow of Harvard University. In late 1940, the National Defense Research Committee established a project at Harvard Medical School (under the direction of Professor Hallowell Davis) aimed toward determining the feasibility of designing and building acoustic weapons, particularly acoustic weapons that might be carried aboard aircraft.

This project was initiated because of reports coming out of Germany that such acoustic weapons had been developed. On this project, Dr. Parrack was appointed as an independent investigator and divided his time between this research and his teaching responsibilities. He continued this work (which provided the basic preparation for his later Air Force assignments) until July 1942.

In July 1942, Dr. Parrack entered into service with the Army Air Corps Army soon to become the Army Air Forces) as an Aviation Physiologist. Aviation Physiologists were assigned the mission of training all flight personnel in the physiology of flight and in such additional subjects as communication during flight, aerial first aid, escape from aircraft and land and sea survival. During the period from 1942 through 1945, Dr. Parrack served with the Eastern Flying Training Command, the First Air Force, and the Western Flying Training Command. On V-J day 1945, he was assigned to the Western Flying Training Command, Las Vegas, Nevada. On the cessation of hostilities he was directed by the Base Commander, to establish a school, including both high school and college subjects, training military personnel being held at the Base pending separation from the Service. This school was established in approximately 7 days and continued to function until the end of 1945 when most of the personnel on the Base were separated from the Service.

In mid-January 1946 Dr. Parrack was transferred to Wright-Patterson Air Force Base and assigned to the Aero Medical Laboratory of the Engineering Division, Air Materiel Command. At this time, he was asked to outline and plan a program of research on sound and vibration that would include studies on the effects of sound and vibration on men in all of the operational environments found in the Air Force. This program was approved and implemented in April 1946. Dr. Parrack continued the direction of this program until late 1953 at which time he was assigned to a full-time job of coordinating and exercising technical direction over an integrated Air Force-wide research program related to noise and vibration, its generation, its propagation, its effects, and its control. He has continued this function until the present date.

In late 1952, while serving as Chief of the Bioacoustics Section, Aero Medical Laboratory, Dr. Parrack was appointed as Technical Coordinator, R. & D. Technical Areas, Noise and Vibration, and was directed to prepare a plan that would integrate all research and development effort in the Air Force in this area into a single program. He performed these planning studies during the early part of 1953 and after the plans had been submitted to Hq Air Research and Development Command he was assigned the full-time job of coordinating the program resulting from his planning activities.

During the period from 1946 to the present time Dr. Parrack has, from time to time, been assigned to a number of special activities which are outlined in subsequent pages of this biographical sketch. Likewise, the technical societies in which he holds memberships are listed in this supplement together with his publications pertaining to noise and vibration.

Special Assignments and Scientific Society Memberships

Membership in Scientific Societies

Sigma Xi (Honorary Scientific)
American Physiological Society (Member)
Federation of American Societies for Experimental Biology (Member)
Acoustical Society of America (Fellow)
American Association for the Advancement of Science (Member)

Current Special Assignments

Armed Forces-National Research Council: Committee on Hearing and Bio-Acoustics—Member.
Council of Armed Forces National Research Council: Committee on Hearing and Bio-Acoustics—Technical Advisor to AF Council Member.
Armed Forces National Research Council: Committee on Hearing and Bio-Acoustics, Working Group No. 34—Community Noise Problems—Member.
Acoustical Society of America: Committee on Noise—Member.
American Standards Association: Sectional Committee S3—Liaison Representative.
American Standards Association: Exploratory Committee S-3-X-20, Criteria for Community Noise of Sectional Committee S3—Liaison Representative.
American Standards Association: Sectional Committee Z-62, Uniform Industrial Hygiene Standards—Writing Subcommittee on Noise and Vibration—Member.
NOISE CONTROL—Editorial Board—Member.
International Organization for Standardization—Technical Committee No. 43, Acoustics—Working Group #8—Member.

Past Special Assignments

Armed Forces-National Research Council: Committee on Hearing and Bio-Acoustics (CHABA), Working Group 33 to evaluate bio-acoustic problems of rockets, missiles, satellites and space operations—Member.
Armed Forces National Research Council: CHABA, Working Group 28—Community Aspects of Jet Aircraft Noise and Flight Operations—Member.

In other places they are also strong enough to completely stop certain other human activities or to make the efficiency of conversation and like activities very low.

Now, I don't want to carry this any further because I think it was adequately discussed yesterday. I do want to summarize and say that sounds from aircraft, missiles, and rockets are noise when they produce undesired effects on man, such as physical damage or impairment of activity. They are noise when they alter plans or activities a man wants to carry out.

Armed Forces National Research Council: CHABA, Working Group 26—Program for Fourth Annual Meeting of CHABA—Member.
Armed Forces National Research Council: CHABA, Working Group 25—Individual Audiometric Criteria—Member.
Armed Forces National Research Council: CHABA, Working Group 22—Criteria for Hazardous Noise Exposure—Member.
Armed Forces National Research Council: CHABA, Working Group 21—Hearing Conversation Data and Procedure—Member.
Armed Forces National Research Council: CHABA, Working Group 6—BENOX Evaluation Member.
Armed Forces National Research Council: CHABA, Working Group 1—Biological Effects of Noise, Exploratory (BENOX)—Member.
National Advisory Committee for Aeronautics—Special Subcommittee on Aircraft Noise—Member (March 1952 to January 1959).
Civil Aeronautics Administration: National Aircraft Noise Abatement Committee—Member.
Armed Forces National Research Council: Air Force Council Member: CHABA, February 1953 to November 1956.
American Standards Association: Exploratory Subcommittee Z24–X–2 to explore the possibility of establishing bio- and psycho-acoustic criteria for noise control. Member, May 1952 to 1954. Report "The Relations of Hearing Loss to Noise Exposure" prepared 1954.

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3. Parrack, Horace O., and Donald H. Eldredge, "Interpretation of Data-Noise Survey, Brookley AFB," AMC Memorandum Report No. MCREXD–695–71E, May 5, 1949, 9 pages.
4. Parrack, Horace O., "Noise Hazards and Their Prevention," proceedings of the National Safety Congress 1949, National Safety Council, Chicago, Ill., 1949, 3 pages.
5. Parrack, Horace O., "Interpretation of Data—Noise Survey, Kelly AFB," AMC Memorandum Report No. 695–71F, May 17, 1949, 13 pages.
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They are noise when they interfere with the timing of these activities as, for example, the interruption of a long-distance telephone call.

They are noise when they reduce the effectiveness of operations, let's say, maintenance of our aircraft, or landing instructions given by a control tower to pilots of aircraft.

They are also noise when they evoke interactions between groups of people such as communities, which induce or cause them to take antagonistic or conflicting positions.

Now, I have discussed this in considerable detail in an article which has been submitted for the record, the title of this article is "Noise, Vibration, and People."

(The article referred to is as follows:)

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NOISE, VIBRATION, AND PEOPLE

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FIG. 1. Jet aircraft landing or taking off, such as this B-47 with its six engines and rocket assist, may be noisy to airport neighbors, but these noise levels are not high enough to produce hearing damage or severe physiological effects on the community residents.

TO cover the area suggested by the title, the scope of this paper must be broad—very broad. A simple statement portrays best this breadth of scope: "When no people —no men—are involved, machinery noise and vibration problems do not exist!" The statement is true because all machines are inventions of people—of men. It is true also because no machine has the capacity to sense, to evaluate, and to predict the future consequences of vibration or exposure to sound. Since the very first machines were invented, the vibrations and the sounds they produce have created problems for people—and for people alone.

Never has a motor complained because vibrations were tearing it to bits. Only the operator or the owner—people—could foresee the consequences. These people, and they alone, could visualize the cessation of production, the cost of repair and replacement. No *sensitive mechanism* controlling a machine process has ever been heard to say, "This noise drives me crazy," as the control pointer dashed madly *off scale*. Only the men at the control console—people —sensed a problem. They alone could visualize the danger to other men in another part of the plant, the consequences of producing an inferior product, or the possibility that the whole operation would come to a grinding halt. Vibrations and sounds produced by machines are problems because: (1) they produce undesired effects on men; (2) they alter men's plans; (3) they reduce the effectiveness of operations men desire to carry out; or (4) they induce antagonistic interactions among groups of men.

• Presented at the 24th Annual Meeting of the Institute of Aeronautical Sciences in New York, January 23–26, 1956.

HORACE O. PARRACK
WRIGHT AIR DEVELOPMENT CENTER

Noise, *Vibration*, and People

Aircraft and their support equipment are recently developed machines. In operation they also generate vibrations and sounds. Again, these sounds and vibrations create problems by producing direct and indirect effects on men—people. No airframe structure complains about the forces applied to its outer surface by varying sound pressures, although its structural elements may be weakened by the action of these forces. Only people, the men who must use the aircraft to perform a mission with speed and safety, are faced with a problem. No electronic computer or other control device within an airframe complains when *shaken about* by vibrations of the airframe or by the sound waves that impinge on its housing. Failure of this equipment creates problems only for those people who desire to arrive at a particular destination or who desire to complete the flight in safety.

Operators of aircraft have a mission to accomplish. They may desire to transport passengers profitably; they may wish to carry freight from one point to another; or they may have some defense assignment to complete. Sounds and vibrations generated by the aircraft affect their operation in direct and specific ways. Passengers aboard an aircraft may desire to carry on conversation. The sounds within the aircraft may thwart this desire. The operator, to accomplish any mission, must maintain the aircraft. Again, sounds and vibrations produced by the equipment adversely affect the performance of maintenance personnel. These effects of vibration and sound on men—people—influence passenger comfort and satisfaction; flight reliability and safety; the speed, safety, and effectiveness of the entire operation.

Aircraft flight operations are initiated by taxiing and take-off and terminated by landing and taxiing. These operations and essential maintenance operations generate sounds that propagate through air to distant locations. Many persons, both inside and outside the airfield boundaries, are exposed to the sound. These persons react to their noise exposure. There are interactions among groups of these persons and the owners, managers, supervisors, and operators of the air facility. These reactions and interactions of people generate a group of community problems attributable, at least in part, to the effects of exposure to aircraft noise.

A complete discussion of the topic *Noise, Vibration, and People* would consider all the effects of sound and vibration. Today specific aspects of the over-all problem will be discussed by various individuals. My discussion of the sounds and vibrations produced by aircraft will be limited primarily to some of their direct and indirect effects on men—people. This broad introductory outline has been drawn to show that one problem created by the sounds and vibrations generated by machinery is never discrete and separable from others: that problems pertaining to effects on structures and equipment are always accompanied by problems pertaining to men—people; that problems related to the effects on people always generate problems pertaining to the design, application, or operation of the machines; that effects on people engender human reactions and interactions that affect communities, operators, and owners. Adequate solutions to problems of this type can be obtained only through comprehensive technical programs carried out by teams composed of specialists in each of the technical areas covered in this general outline.

Some Integrative Concepts

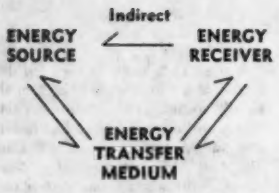
In planning and carrying out research or engineering development in the several areas described in the introduction, it has been necessary to develop among the members of the technical team a *common understanding* of the problems. The use of certain definitions and general concepts has promoted this *common understanding*. Stating some of the definitions used and describing some of the concepts employed may assist us here.

Acoustic Energy. This term is used to describe energy generated, released, and propagated either as *mechanical vibrations* or as sound waves (noise).

Noise. This word is used to describe any "unwanted" or "undesired" sound. This definition always implies that a man has heard the sound and made a decision about it. The decision is: "This sound is undesirable at this place, at this time, and in relation to the activity in which I am now engaged."

The Acoustic Energy System.[1] The concept of an *acoustic energy system* has been used in organizing data, planning research, and developing energy control devices. This system is conceived to be composed of three major elements which are in continual interaction. The major elements composing the system are: (1) *acoustic energy sources;* (2) *acoustic energy transfer media (paths);* (3) *acoustic energy receivers.* The *energy source* is the process, device, machine, or person that releases energy in the form of sound waves or mechanical vibrations. The *energy transfer medium* is the material substance (air, earth, structure, etc.) in which acoustic energy is carried away from the source. The *energy receiver* is the object (structure, machine, equipment, person) in contact with the transfer medium which receives or absorbs the acoustic energy transferred to its immediate vicinity or to its surface.

Acoustic energy flows through this three-element system. The energy level at any point and its flow are determined by the properties of the three system elements and by the interactions among them. The principal energy flow is as follows: ENERGY SOURCE → ENERGY TRANSFER MEDIUM → ENERGY RECEIVER. Usually there is some energy loss in the transfer medium, and our most effective means of sound control are based upon altering the transfer medium to increase its capacity to dissipate acoustic energy. The energy level at the source, its flow, and its level at other points in the system are influenced by interactions among the elements of the system. The principal interactions may be diagrammed as follows:



Use of this *system concept* aids in the analysis of complex problems. Apparently specific and unrelated problems can be organized, using the concept, in appropriate relation one to the other. The concept can be used as a framework in planning programs and is especially useful in analyzing them for completeness, balance, and integration of effort.

Application of the Acoustic Energy System Concept

The features, implications, and applications of the concept of an *acoustic energy system* have been described in general terms. Let us now examine two problems, using the concept. The first problem: damage to airframe structures caused by sound waves generated by turbojet engines. The engine is the *acoustic energy source*. Air between the engine and the airframe is the *acoustic energy transfer medium*. Some part of the airframe is the *acoustic energy receiver*. At once we see that we need to state quantitatively all of the properties of each component of the system. In addition, we must determine and describe quantitatively the interactions of the system components. Practically, it may be a very difficult task to gather all of the quantitative data. The task is made more difficult by the fact that the over-all system operates in many different environments, each of which may influence the basic properties of the system elements and also their interactions. However, the system concept enables us to identify the parts of our task and to assess the relative importance of each. We shall see that this problem, however difficult it may be, is relatively simple when compared with some other sound and vibration problems associated with air operations.

The second problem pertains to the determination of the effect on a man of the sound produced by the same turbojet engine. The man is inside the airframe and is wearing personal equipment to reduce the sound level at his ears. The energy source is the same, the engine. The transmission medium is different and is complex. It is made up of air–airframe wall–air–protective device–air, considering the man's ear as the receiver. However, the effect of sound on man is not confined to effects on his ears. We have a second transfer medium to consider, air–airframe wall–air–the man's clothing. The energy receiver is man, but, as a minimum we must consider separately the properties of the ear and those of the general body surface as energy receivers. Specification of the source requires the same data required in the first example. The transmission medium, since it is complex, is far more difficult to describe quantitatively. The interactions among the components of this transfer medium add to these difficulties. The characteristics of the receiver–man–are to be quantified. However, specification of the characteristics of the ear alone requires many sets of data depending on the function under study. If we wish to avoid loss in hearing sensitivity, we need one set of data. Other sets are required when the purpose consists of communication by voice signals, detection of special signals from instruments, or efficient performance of some other hearing task. In this problem, specifying the basic properties and describing the interactions among system components are more difficult tasks than in the first problem. This is particularly true with relation to the *transfer medium* and to the *receiver*. Analysis, using the *acoustic energy system* concept, pinpoints the difficult phases and provides an integrating framework upon which to base a comprehensive investigation.

Essential Quantitative Data

Application of the *acoustic energy system* concept in analyzing two problems showed that certain quantitative data about each element of the system were required for solving them. In general, the solution to any problem pertaining to acoustic energy, its generation, its transmission, its action, and its control will require the same classes of data. The principal classes of data required for each system element will now be described.

Energy Sources

In describing or specifying a source, it is necessary to determine: (1) the total acoustic power output; (2) the acoustic spectrum or frequency distribution of the power; (3) the directivity pattern of the source, that is, the spatial distribution of the power; (4) the principal subsources and their characteristics (for a complex or multiple source). It is usually necessary to obtain this data for each significantly different condition under which the source is operated. The time schedule for the operation of the source is frequently required. Detailed knowledge of the mechanisms of sound generation is sometimes essential and always desirable.

Energy Transfer Media

Transfer media fall into two principal categories: (1) natural media (air, earth, water); (2) artificial media (man-made structures, equipment, etc.).

Natural Media

Air, or the atmosphere, is of primary interest to us. To specify its behavior as an energy transfer medium one must state: (1) the basic constants that describe sound propagation; (2) the energy loss that accompanies propagation; (3) the extent to which air behaves linearly as a function of input sound pressures. Variations of these constants must be related to variation in temperature, to variation in density (altitude), to relative motions within the air mass, and to interactions between the air mass and the earth's surface.

Artificial Media

The same classes of over-all specifications are required for these as

were required for natural media. Since most of these media are complex and frequently include air as part of the structure, the task of specifying them is a large and difficult one. Perhaps the most important fact about them is that they are usually designed to accentuate *energy loss* during transmission of the sound or vibration.

Energy Receivers

In general, the response of any receiver must be quantitatively described as a function of the variations in a quantitatively defined acoustic field at its surface or in its immediate environment. Usually, separate sets of data are required for each specific function the receiver performs. Let us now confine our attention to man as the receiver of acoustic energy. We shall tabulate the human functions that should be described in relation to the effects upon them of different levels of acoustic energy.

Acoustic energy in man's immediate environment induces physical or mechanical alterations of the body surface. These mechanical alterations may involve the entire body surface. They may involve only specific segments of the body surface, or they may be restricted to specialized surface structures known as sensory receptors. Mechanical activity induced in the entire body surface or in specific areas of this surface activate other receptors just beneath these surfaces. The mechanical changes may be propagated (sound waves) through the body tissues to activate other sensory receptors located at varying distances from the surface. The mechanical activity in the body surface may produce local physiological changes (circulatory and other changes). The activation of sensory receptors results in activation of the peripheral and central nervous systems. Activity of the central nervous system results in additional physiological activity scattered widely throughout the body. The messages initiated by the sensory receptors travel through the nervous system to the brain. Activity of this part (brain) of the nervous system results in perceptions or sensations—for example, hearing the sound or feeling the vibrations. These perceptions (sensations) are representative of psychological activity. The brain may call from storage information received in the past. It may remember a news item about an aircraft crash. By combining information coming in over the receptor system with that in storage, the brain initiates a form of activity (on the part of the man) that is known as a complex response—a complex behavioral reaction. These complex behavioral responses may range from *stating that a sound is present* through *extracting the meaning* from spoken word signals to *initiating a claim* or taking other sim-

FIG. 2. Personnel are shown starting the F-102 aircraft. Note that standard sound-excluding earmuffs are required to protect ears adequately from noise of the engine. The auxiliary power unit operator is wearing also an inclosed microphone to enable him to communicate with the pilot. Similar equipment is used by all personnel performing maintenance operations.

ilar action against the operator of the source of acoustic energy.

This is only the barest outline of the possible reactions of man to acoustic energy. All of the physical, physiological, psychological, and complex behavioral responses of which man is capable must be measured quantitatively. These quantified responses must be related to the parameters of the acoustic energy field (also stated quantitatively). When considering men who are exposed to aircraft noise, we must obtain information on the relation of the acoustic energy to *at least* the following human responses: (1) mechanical damage to the body or to some part of it (including sense organs); (2) pathological changes induced in some body part (particularly sensory receptor mechanisms); (3) reversible impairment of sense organs (hearing organ, etc.); (4) immediate functional disability (reduced precision of manual acts); (5) impairment of communication by speech signals; (6) arousal of general annoyance or dissatisfaction; (7) arousal of apprehension or fear; (8) initiation of various complex antagonistic activities against the energy source or its operator.

The significance of each of the responses of people to acoustic energy will vary for different groups of men. In connection with the operation of aircraft and the conduct of essential supporting activity, the relations between acoustic energy and the various human responses (as outlined above) should be evaluated for at least the following groups of people:

1. Occupants of the aircraft.
   a. Air crew.
   b. Passengers.
2. Ground support personnel.
   a. Aircraft maintenance crews.
   b. General supporting personnel.
   c. Managerial and flight control personnel.
3. Men outside the air base or airport.
   a. Community members affiliated with air operations.
   b. Community members not directly associated with any air operations.

Some Data on People vs Acoustic Energy

Hundreds of investigators employing both field studies and laboratory experiments have sought to determine the relations among human responses and the parameters of the acoustic energy fields to which people may be exposed.[5] A great majority of these investigations have been concerned with the various functions of the hearing mechanism alone. Some of them have explored complex behavioral responses of men, particularly the effectiveness with which certain everyday tasks can be carried out in noise. Usually, the energy level of the sound field employed has been quite low or moderate. There have been relatively few studies on human reactions to very intense sound fields.

Recently an attempt has been made to review and evaluate many of these studies.[6] Persons exposed to sound fields of over-all levels up to 120 decibels (reference 0.0002 dyne/cm^2) and engaged in mental or motor tasks not involving communication perform these duties without significant decrement. In some tasks performance is improved. It is probable that additional effort is required to maintain the level of performance. On the other hand, noise has adverse effects on communication by speech or other auditory signals. This effect is of major practical importance for industrial and office duties. The *annoyance value* of noise is apparently related to its spectrum, and in steady noises those containing high frequencies are more annoying than those containing low frequencies. It has been clearly shown that sound (noise) can cause temporary decreases in hearing sensitivity and that long-time exposure to certain levels can cause a permanent decrement in the ability of the ear to detect sounds.

The problem of man's response to acoustic energy is an important one for any operator of aircraft and their supporting equipment and facilities. An attempt has been made to collect and to place in one document some of the more important data bearing on this problem.[5] Recently some exploratory studies[6] were carried out in an effort to evaluate the effect on man of exposure to the intense sounds that exist very close to current turbojet engines. A committee has made a special study of the relations between exposure to sound (noise) and the impairment of the hearing function in exposed persons.[7] Data gathered and evaluated in the course of the studies just cited will provide the principal bases for our further examination of the effects of acoustic energy on man.

Mechanical Damage to the Human Body

Data from studies on the effects of blast waves show that the human body (with the exception of the hearing organ) can withstand short-time exposure to fluctuating pressures unless the pressure peaks exceed two or more atmospheres. There is no information about the consequences of frequent repetitions of this kind of exposure. Parts of the hearing organ appear to be most susceptible to mechanical damage. Again our data are very limited, but they indicate that exposing the ear to alternating pressures whose rms values are of the order of 0.02 atmosphere (160 db) will probably result in immediate rupture of the eardrum. This effect has been observed upon exposure to a tone (6500 cycles per second) and to a complex noise (jet type) where the measured sound-pressure level was about 160 db. However, the sound pressures were measured when the exposed person was not in the sound field, so that the actual pressure at the eardrum may have been still higher during the exposure. In any case, the ear should be protected if personnel enter or work in areas where these sound-pressure levels are found.

Immediate Functional Disability

There are numerous reports, which it is not possible to document reliably, that exposure to the sound-pressure levels measured near turbojet engines results in a

variety of impairments of men's functions. Let us now examine the available relevant facts.

Sense of Position in Space

Man's sense of position in space (orientation) is derived from the integrated action of several sense organs, especially the non-auditory part of the inner ear (labyrinth), the eyes, the muscle sense, and touch from feet, legs, body, and neck. Any one of these inputs can be lost without serious reduction in performance. More serious disturbances result from conflicting information from two or more of these sense organs, such as that resulting from a *false stimulation* of one of them by unusual means (direct stimulation of the labyrinth by sound, for example). For sounds in the frequency region near 1000 cps, stimulation of the labyrinth begins at pressure levels around 135 db. Symptoms of nausea and vomiting, nystagmus, shifting of the visual field, feelings of forced movements, and staggering or falling are known to be closely associated with *abnormal* or *excessive* stimulation of the organs for orientation. Activation of the central nervous system by stimulation of other sensory mechanisms may cause other functional changes, such as changes in muscle tone, increase in deep tendon reflexes, and incoordination. Such responses appear to be *just initiated* when persons are exposed to sound-pressure levels between 135 and 140 db. An evaluation of current information leads to the conclusion that sound-pressure levels of the order of 140 db may be the threshold levels for the initiation of disturbances to a large number of important body functions. At present, protecting the ear or head appears to prevent most of these disturbances. Today our best action is to minimize human exposure to these sound levels. In addition, investigation of the effects of acoustic energy of levels in excess of 140 db must be accelerated. The reliable determination of the consequences of continuing (long-term) exposure to sound-pressure levels in the region above 140 db is yet to be accomplished.

Painful Sensations in the Ear

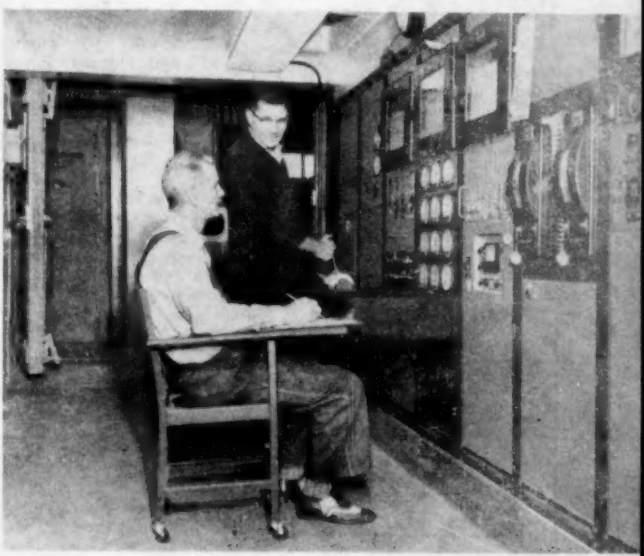
Exposure of the unprotected human ear to sound-pressure levels around 140 db results in a painful sensation localized in the middle-ear region. This response occurs at about the same sound-pressure level for all frequencies in the speech frequency range. At lower frequencies and at higher frequencies somewhat higher pressure levels are required to produce pain. The pain is reported by persons who are exposed for the first time to a pressure level between 135 and 137 db. If the exposures are continued over a period of time, higher sound pressures (somewhat above 140 db) are required to arouse the painful sensation. Pain is usually an indicator of tissue damage or of incipient damage. For this reason exposure to sound levels that produce pain should be avoided. Protecting the ear prevents painful stimulation, but *caution* in exposing personnel to these higher sound levels is recommended, at least until we know more about the effects of exposure to sound levels in excess of 140 to 145 db.

Pathological Changes in the Body

This term is here applied to an irreversible change produced in some part of the body. Such changes usually develop over a period of time, although permanent changes can be produced abruptly.

The hearing organ is the part of the body of greatest importance when we are considering exposure to sound. It has been shown [9] that under appropriate noise exposure conditions the human ear, particularly the inner ear, can be permanently altered so that it cannot detect certain sounds. This condition

FIG. 3. Engine test personnel here are performing essential tests on turbojet aircraft engines. In this control room, test personnel converse in a normal voice, although the sound level in the engine test cell may exceed 150 db. Easy communication is possible because the test cell is separated from the control room by heavy walls and access to the test cell is through a corridor closed by acoustical doors. The corridor and its two doors can be seen at left.



is referred to as *hearing loss*, or deafness. Hearing loss can vary in magnitude from an amount which the person never notices to an amount which makes it impossible for him to detect any sound, no matter how strong it is. Hearing loss can and does occur in persons who have had no significant exposure to industrial noise. Also, it is clear that industrial noise exposure can accelerate the development of a hearing loss.

As soon as one attempts to specify noise levels in which people may work without incurring a risk of developing a hearing loss, he faces almost insoluble problems. Nearly all, if not all, people lose some of their hearing capability simply because of changes that accompany aging. This type of hearing loss appears to be indistinguishable from that resulting from noise exposure. In a practical situation, for a given individual, there is always the question: How much hearing loss results from aging and how much results from noise exposure? Another important question is: How much and what kind of hearing loss causes a handicap sufficient to be considered undesirable? There are still other relevant questions, such as the following: What percentage of exposed people shall be protected under the specified noise levels? Since there are large individual differences in susceptibility, shall one attempt to protect 50%, 80%, 90%, or 99% of the exposed persons? Since different noises apparently differ in their effectiveness as producers of hearing loss, how shall noises be specified and exposure measured?

Table I. Tentative Short Exposure Time Criteria

Allowable Exposure Time	Level of Jet-Type Noise
480 min	100 db
240 min	103 db
120 min	106 db
60 min	109 db
30 min	112 db
15 min	115 db
7.5 min	118 db
3.0 min	121 db
1.5 min	124 db

It is true that these questions exist and that there is continuing controversy about an appropriate answer for each. However, some of us have had to make decisions. A basic criterion was established to use as a guide in designing and developing noise control equipment and procedures. This criterion[3] defines the maximum sound-pressure level per octave band of frequency for a noise field in which persons may work with the ears unprotected. It assumes that the noise is wide-band, has a reasonably continuous time character, and has no substantial sharp energy peaks. The levels are considered safe in terms of exposures during working days for durations up to a working lifetime. The criterion was proposed as a tentative one subject to revision as new data became available. The contours are to be considered as zones, with variations of one or 2 db in either direction to be considered as probably acceptable. It is a criterion designed to reduce the *risk* of an individual's developing a hearing loss. There was some uncertainty about the *degree of risk* permitted by the criterion. The criterion is shown in Fig. 4. Note that the sound-pressure levels are given for each octave band. No value is placed upon the over all sound-pressure level in this criterion. This emphasis on octave-band levels was deliberate in view of the fact that current information indicates that not all regions of the frequency spectrum have the same capacity (at a given sound-pressure level) to produce hearing loss. In other words, the wide-band noise criterion for long-time exposure to continuous noise places primary emphasis upon the sound-pressure levels in specific frequency bands and not upon the integrated pressures developed by the bands combined.

The criterion, developed three or more years ago, has recently been reviewed to determine whether it should be revised. Although some information has been accumulated since the criterion was established that indicates revision should probably be made, this information was not considered sufficiently substantial to justify revision at this time. Evaluation of the new information does, however, permit formulation of some statements that may define more clearly the significance of the criterion. It was agreed that the criterion should continue to be expressed as pressures per octave band for all of the octave bands shown in Fig. 4. It was agreed that the wearing of protective equipment should be mandatory whenever personnel are exposed to sound-pressure levels that equal or exceed those stated in the criterion. If the pressure equals or exceeds the criterion value for any one octave band, protective equipment must be worn. The criterion is a basic criterion for lifetime exposure, where the specified lifetime is twenty-five working years. Exposure is assumed to be continuous throughout normal working days within the working lifetime. It was reiterated that the criterion applies to wide-band noise, continuous in time, and without any significantly large pressure peaks.

The criterion is based upon a *risk* concept. That is, it specifies noise levels in which a group of people may work and be assured that *not more than a specified percentage* of the group will develop a hearing loss equal to or in excess of a *specified acceptable value*. The acceptable hearing loss for use with this criterion pertains to hearing loss for speech signals. The frequencies considered important are 500, 1000, and 2000 cps. Any hearing loss for these speech frequencies that is *less than the value of the hearing loss for speech* at which veterans' compensation begins is considered acceptable. This is the *now agreed limit* for the permissible *hearing loss*.

Now, in any group (population) either *exposed to noise* or *NOT exposed to noise*, a certain number will develop hearing losses that exceed the permissible value. *Noise* has no bearing on the hearing loss for these persons, and a means must be found for allowing for their presence in a *noise-exposed* population, because NO amount of protection will prevent their hearing

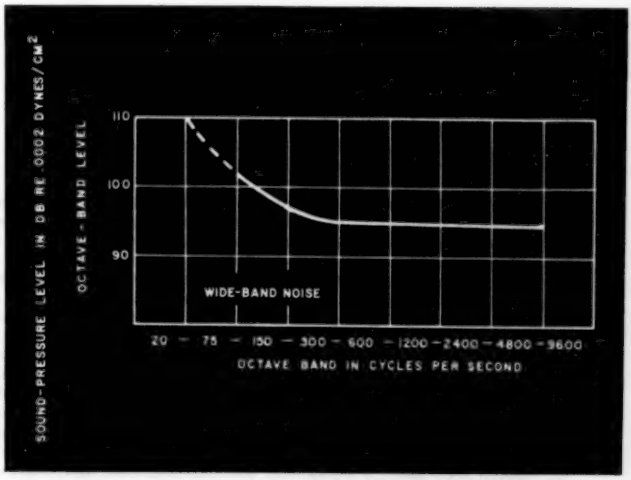

SOUND-PRESSURE LEVEL IN DB RE .0002 DYNES/CM²
OCTAVE-BAND LEVEL
110
100
90
WIDE-BAND NOISE
20 — 75 — 150 — 300 — 600 — 1200 — 2400 — 4800 — 9600
OCTAVE BAND IN CYCLES PER SECOND

FIG. 4. Damage risk criteria for octave-band levels of continuous wide-band noise for lifetime exposure (eight hours per day) of the unprotected ear.

loss. These persons may be separated into at least two groups. One group develops hearing loss *solely* as a result of aging, of living the twenty-five work years. A second group develops hearing loss because of disease, exposure to chemical agents, or various other factors in no way related to noise exposure. Noise exposure will not influence the hearing loss of these two groups, and such hearing loss must not be charged to noise exposure. Some information is available on the number of people that will develop hearing losses in excess of the agreed acceptable limit because of aging processes. There is less certainty about the second group; it may include about one tenth of the population.

By examining the criterion shown in Fig. 4 in the light of some recent data, one can make some estimates of the degree of risk confronting the noise-exposed population. It is estimated that approximately two thirds of the exposed group will not develop hearing loss in excess of the defined acceptable value. About one tenth of the population will develop excessive hearing loss from aging alone (not affected by noise exposure). Perhaps another one tenth of the population (perhaps even a larger part) will develop hearing loss for REASONS OTHER THAN NOISE EXPOSURE. This means that about one sixth (perhaps less) of the population (those most susceptible to the effects of noise) could develop hearing loss from exposure to noise fields allowed by the criterion. There is a RISK involved for these members of the exposed group.

Because of the RISK to susceptible persons from exposure to noise fields meeting the criterion, it is necessary to employ *monitoring audiometry*. Monitoring audiometry is the use of pure-tone audiometry to test the hearing thresholds of persons working in noise for the purpose of detecting those susceptible to hearing loss from noise exposure. It also provides justification for assigning susceptible persons to duties where noise exposure creates no problem. The monitoring audiometric test program will also detect persons having hearing loss for reasons other than noise exposure and make it possible to determine how these persons may be employed usefully. The combination of risk criterion and monitoring audiometry assures protection to all persons who can possibly be protected.

In actual practice, the criterion for maximum noise level may be better than outlined above. Exposure may be less than twenty-five years. In air operations many persons do not receive eight hours of exposure daily, each work day, over the twenty-five-year period. In order to further reduce this risk it is recommended that ear protection be employed beginning at noise levels 10 db below the criterion values.

Short-Time Exposure

The criterion for noise level, we have discussed, applies to full-day exposures of eight hours. In many practical situations exposure per day is shorter. There have been requests for information about the noise level limits for such short exposures. The basic criterion has been extended. The basis for this extension is the assumption that an acceptable exposure for short time periods is one that delivers to the ear *an amount of acoustic energy equal to that delivered in eight hours* when the exposure levels are those stated in the basic criterion. *Limiting exposure times* have been computed on this basis for noise fields having the characteristics of the noise fields generated by a turbojet engine operated at power settings of *cruise* or above. By comparing the octave-band distribution of the noise energy under these conditions of engine operation one notes that the over-all reading would be about 100 db (ordinary sound-level meter) when the *basic* criterion is satisfied. This value, 100 db of jet noise, is the value allowed when the exposure time is eight hours. Then each time the level is increased 5 db the exposure time must be cut in half. The tentative short exposure time criteria is indicated in Table I.

Table II. Speech Interference Levels for Normal Speaking Voice

Distance (ft) from Listener	0.5	1.0	2.0	3.0	4.0	5.0	6.0	12.0	24.0
Speech Interference Level (db)	71	65	59	55	53	51	49	43	37

These are maximal daily exposures and indicate that for the stated level of noise (as defined above) and the stated time of exposure, protection should be used. Protection should be used for any exposures in excess of those specified. It is probable that persons exposed to noise fields in accord with these short-time criteria run less risk of developing hearing loss than they run when exposed under the conditions given by the basic criterion.

These criteria are not recommended necessarily for use by others. They do, however, suggest an approach to be used in establishing criteria for similar situations.

Reversible Impairment of Sense Organs (Ear)

Upon exposure to sound levels much lower than those which produce permanent change, the ear loses some of its sensitivity. This loss is called a temporary hearing loss or temporary threshold shift. Temporary threshold shifts can be used to evaluate (to a limited extent) the susceptibility of an individual to permanent hearing loss. Those persons who develop an unusual amount of temporary threshold shift for a given noise exposure are considered susceptible. If they return to their normal hearing sensitivity much more slowly than the average for the group, this is also a mark of increased susceptibility. In our practical situations these temporary threshold shifts are of importance primarily because they may be used to detect persons susceptible to permanent hearing loss.

Impairment of Communication by Speech Signals

Men depend on the detection of speech signals by the human ear for a vast majority of their everyday communications. These communications between men may be two-way (direct person-to-person or over a voice communication network) or one-way (listening to radio or the audio channel of television). Efficient performance of many tasks requires adequate communication among co-workers. Satisfaction or dissatisfaction with many everyday living situations may depend on the quality of voice communication that can be maintained. When noise overpowers the speech signal (auditory masking) and disrupts voice communication, many essential activities are slowed. Also, many otherwise pleasing activities may be made annoying or unpleasant.

The quality of voice communication required varies with the activity in which one is engaged. Complexity of the message and familiarity with the subject matter (or lack of familiarity) influence the ease with which a specified level of communication can be maintained. A detailed statement of the requirements for each of the communications jobs men perform daily would be impossible here.

There are several methods for evaluating the effect of noise on voice communication. Some are quite complex, some relatively simple. One method [8] frequently used in engineering problems for estimating the amount of interference to communication that noise produces will be outlined.

In this method the noise is measured and analyzed using octave-band filters. The sound-pressure levels read in decibels for three octaves (600–1200; 1200–2400; 2400–4800) are added together and divided by 3. The result is a number known as the *speech interference level*. It is expressed in decibels (reference 0.0002 microbar). This number can be used to state allowable noise interference with specific communication duties. If one uses a normal speaking voice, he may be heard well enough to carry on a reliable conversation when the distances shown in Table II separate him from the listener and when the stated speech interference level is present.

Telephone use is rated *Satisfactory* when the speech interference level is less than 60 db; it is rated *Difficult* when the range of speech interference level is 60–75 db; when the speech interference level exceeds 75 db, use of the telephone is impossible. The above examples illustrate the use of the method. Data are available for a variety of activities. For critical problems more complex methods of computing interference with communication are available.

Arousal of General Annoyance

Annoyance and expressions of annoyance are complex reactions. Annoyance can exist and not be expressed. Annoyance at the presence of a noise can arise from interference with conversation; from its having aroused one from sleep; from its effect in rattling windows etc.; or from a variety of other effects noise may produce. Today we have virtually no data on noise levels that create annoyance. In fact, we probably *do not have a commonly accepted meaning* for the word *annoyance*. Annoyance because noise interferes with sleep and rest has been reported by many persons. The levels of the noises complained about varied from about 40 db over-all to 70 db or above. The level of the usual background noise in the particular environment has an influence where complaints are of the type cited. Reliable, or perhaps one should say confirmed, data are yet to be obtained in this area of human response

Arousal of Apprehension or Fear

Apprehension and fear are both complex responses. Certainly they never depend upon the immediate stimulus alone. Perhaps they

are nearly completely responses to stored (remembered) information. The noise may simply activate the brain in a manner that allows it to act using the stored data. In this case noise is simply a *triggering* agent. In order to start the response under these conditions, the noise need only be intense enough to be detected (heard) and identified as coming from a particular source. Intensity of fear may be correlated with noise intensity—we do not know. The future must provide us with most of our answers in this entire area.

Initiation of Complex Antagonistic Activities

These responses of people are very complex. There may be a great deal of information somewhere about the initiation, development, and spread of this type of response, but this data has not been collected and properly related to noise exposure or noise levels. Certainly the form of a given response, its intensity, etc., depends on a wide variety of factors that are independent of the noise level, the characteristics of the source, or other parameters that might be used to define the noise. Perhaps noise acts primarily as a *trigger*. Perhaps it acts because it produces speech interference and a variety of other direct effects on man's daily activity. We do not have data now with which to evaluate adequately this class of response. These responses are mentioned because they are *potentially* of major importance with respect to all types of air operations.

Some Data on Sources

Let us now examine briefly some practical *acoustic energy* sources to gain some impression of the characteristics of the *acoustic energy* fields in which men must work. In Fig. 5 we show the relative sound-pressure levels measured around a current jet aircraft. The center for the radii of the measurement circle is located at the jet nozzle. The radius length is 100 ft. The angular separation of the points on the measurement circle is 11.25°. Sound-pressure levels (over-all) are shown for the engine operating at idle, cruise, and military power setting and with the afterburner operating. Note the directivity pattern. The over-all sound level in the direction of maximum radiation is: 140 db with afterburner; 134 db at military; 131 db at cruise; and 94 db at idle. Observe that the sound-pressure level (afterburner) is 28 db higher in the direction of maximum radiation than it is in the direction of minimum radiation of sound. Essentially the same difference is found at military and cruise. At all positions forward of the 90° radius the sound levels are more than 15 db lower than in the direction of maximum radiation. These are important facts to consider in practical operations.

The directivity effects are more strikingly shown in Fig. 6. This figure applies to the same airplane and is based on the same data. Here a sound-pressure level of 120 db (over-all) was selected. Then the distance from the jet nozzle at which this level is found was calculated for the same directions in which measurements were made. Figure 6 shows strikingly the directivity effect and shows also that a reduction of noise level for the direction of maximum radiation, even with appreciable increases in other directions, could be of much advantage in reducing the area exposed to high noise levels during the passage of an aircraft.

These figures are representative of jet aircraft generally. Maximum levels may be higher or lower. The pattern of sound-pressure distribution is quite similar for all jet types. These data illustrate the noise levels in which maintenance personnel must work. They also indicate that reduction of radiation in the direction *now maximum*, with some increase in other direc-

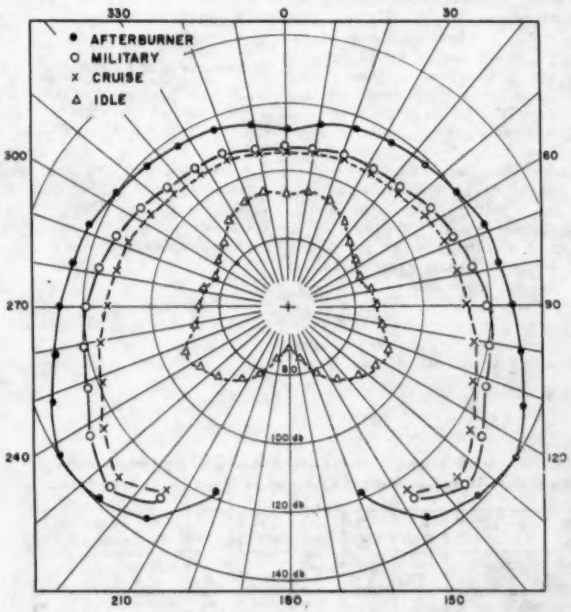


FIG. 5. Fighter ground noise levels at 100 ft.

tions, could improve the situation for people at moderate to large distances from the aircraft.

The Transfer Medium

Sound control devices are all specific, and each set of data is applicable to one device or, at most, to one type of device. These devices, when used, are designed to reduce sound-pressure levels materially at relatively short distances from the source. We shall not discuss them further at this time because it is not possible to present reliable general data.

The atmosphere is important as a transfer medium when sound is propagated to the environment of people located at relatively large distances from the source. The numbers employed by different groups for specifying the effects of the atmosphere vary considerably. The numbers used here are from a set that has been used in working with many noise control problems. These numbers are subject to change as better ones become available.

For problems involving propagation by aircraft (at an appreciable altitude) to the ground, the values for minimal attenuation are used. The actual values may vary. Wind changes the numbers. Temperature gradients may also introduce changes. Using the values cited, we can, however, make estimates of the maximum sound-pressure levels to be expected at a given distance from a source and of the minimum expected sound-pressure levels.

One should note that the increased atmospheric attenuation in the frequency bands used in computing speech interference means that increasing the distance between a source and people results in improved communication. The variability of attenuation indicated by the numbers also implies that at a given location some fixed distance from the same source, interference to communication may vary considerably. Likewise, other effects of noise on people will vary as atmospheric variables alter the sound attenuation, and so the sound level, at a given location.

Men in Practical Noise Environments

Let us now see what conclusions we may draw with respect to people in the noise fields found in practical situations. We shall refer to the data on acoustic energy sources; acoustic energy transfer media; and MEN as acoustic energy receivers. Perhaps we can handle these problems best by considering separately each of our groups of men as acoustic energy receivers. These groups are: occupants of the aircraft; ground support personnel; men outside the air base or airport.

Occupants of the Aircraft

Over the past ten to fifteen years a great deal of effort has been expended in seeking to reduce noise levels inside aircraft. Engine power has increased over the same time interval, so that the problem has become increasingly difficult. However, our accomplishments have been reasonably satisfactory.

Air Crew

Noise creates a major communication problem for members of air crews. However, development of noise control treatment combined with the protection afforded by earphone covers or by flying helmets has permitted adequate communication in most cases. For some duties the situation may now be marginal. Further increases in noise level will probably create several significant problems related to communication, especially in military aircraft. The noise levels in nearly all aircraft are below those levels that create a significant risk of hearing loss, especially when earphone covers or helmets are worn. These devices exclude noise from the ear.

Passengers

In military aircraft passengers could wear hearing protection to advantage. In commercial transport aircraft, especially in some sections, communication is restricted. Sound levels are not excessive, and because of the relatively short exposure and the long intervals between exposures, there appears to be absolutely no significant risk of hearing loss, even in the noisiest aircraft.

Ground Support Personnel

The problems created by noise for ground support personnel vary widely because the duties of these persons vary as does their proximity to the sources. Their problems will be discussed under three subgroups.

Aircraft Maintenance Crews

If we recall Figs. 5 and 6, we shall realize (from the data presented on sound-pressure levels at 100 ft from the jet nozzle) that personnel who carry out maintenance operations on the aircraft engine or any other airframe component are exposed to quite high noise levels when the engines are in operation. If maintenance work must be carried on at a position on the radius of maximum sound radiation, then working in this position will expose the individual to a sound-pressure level of the order of 160 db when he is a distance of about 10 ft from the jet nozzle and

Table III. Sound Attenuation per 1000 ft when Propagation through Air Is Parallel to and Near the Ground Is Given for Octave Bands

cps	20 75	75 150	150 300	300 600	600 1200	1200 2400	2400 4800	4800 9600
Minimum Expected (db)	3.5	3.5	3.5	3.5	4	6	11	19
Maximum Expected (db)	19	19	19	20	22	27	36	56

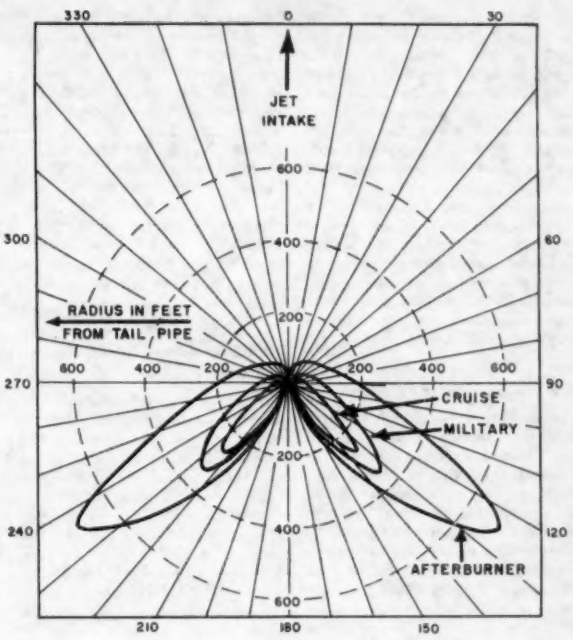


FIG. 6. Fighter aircraft constant sound-pressure level contours of 120 db re .0002 dyne/cm².

when the afterburner is in operation. As Fig. 6 shows clearly, the distance in all other directions at which a given sound pressure is measured is shorter. Since most maintenance operations are performed at positions other than along the line of maximum sound radiation, the sound-pressure levels to which maintenance personnel are usually exposed are less than those which are measured in the direction of maximum radiation.

Figure 7 furnishes additional data on the same aircraft used as an example in our previous discussions. The data contained in this figure is intended for use in evaluating problems pertaining to maintenance duties. It is intended for use with both the *criterion for long-term exposure to noise* and the *criterion for short-time exposure*. If we use the data in Fig. 7 pertaining to military power setting and take the maximum allowable sound pressure to which persons may be exposed without ear protection when the noise is of the jet type, we find: (1) in the direction of maximum radiation the individual should not work closer than about 1500 ft if he is to work for a full eight-hour day; (2) if he works at a position on a line at right angles to the jet axis, he need remain only 300 ft away; and (3) if he were to work at any position 40° to the right or left of the nose of the aircraft, he would need to remain only about 150 ft away. These distances clearly indicate that men must either wear protection during the maintenance work period when the aircraft engine is operated at military power setting, or they must reduce the time of their exposure. In fact, careful examination of the pressure levels around the aircraft (as a function of distance from the jet nozzle) indicates that personnel performing maintenance operations during high power-level operation of the aircraft engine should always wear ear protection. On the other hand, when low power settings (near idle) are used, the individual can perform maintenance operations without wearing protection, but he probably cannot safely work continuously at such duties throughout an eight-hour day. It is, therefore, recommended that all maintenance performed on aircraft when the engines are in operation be performed with the maintenance men wearing ear protection. The risk of developing a hearing loss is a major problem for persons who are engaged in maintenance duties that must be performed while the engines are operated.

Let us select a level of 140 db, one that is painful for the unprotected ear and one to which exposure should be avoided where possible. If the engine in our typical aircraft is operated using the afterburner, a sound level of 140 db is measured about 90 ft from the jet nozzle on the radius of maximum radiation. The distance at which this sound pressure is measured is less than 18 ft for all positions forward of a line at right angles to the jet axis and passing through the nozzle. It is clear that these distances are such that during maintenance activity men are exposed to sound-pressure levels near 140 db during afterburner operation. Use of protective gear is essential. Figure 7 also shows the sound-pressure level at positions where maintenance personnel work while the engines are operating. The position at which the highest level was measured for each engine power level is the one selected. These levels are: idle operation, 104 db; military power, 128 db; with afterburner, 153 db. These levels are slightly lower than are estimated from the general data. This is to be expected, but so are higher levels in some cases. Airframe components, ramp conditions, even the position of the

body and head will alter sound-pressure levels at maintenance positions. The computation using general data is sufficiently exact to permit making decisions about the use of protection and about other questions pertaining to protecting personnel from the effects of the sound. Voice communication is impossible in maintenance positions. Other means of communication must be used. In summary, it may be stated that considering acoustic energy and its effects on men, maintenance personnel work under the least favorable conditions encountered by any personnel engaged in air operations.

General Supporting Personnel

The duties of these personnel and the positions relative to aircraft at which their duties are performed vary widely. When they work in areas that involve a risk to the hearing function, they too should use protective equipment to reduce the level of the sound reaching the ear. Where the number of aircraft is large and engine operation essentially random, the best procedure is to define RISK AREAS and to insist on the use of protective gear by all persons working in these areas. Interference with communication will be a major problem for all of these personnel. Special methods of communication frequently may be required. Those whose duties are inside buildings will receive some protection, but if doors and windows are open this is negligible. Specific recommendations as to the means for minimizing the effects of noise on these personnel must be based upon a careful analysis of the particular operational situation.

Managerial and Flight Control Personnel

Persons performing these functions will experience exposure to noise levels which constitute a *risk to the hearing function* only occasionally. Ear protectors can be used on these occasions. Interference with voice communication will be the principal problem. This interference is more significant because efficient and safe operations depend on the quality of the communications that can be maintained during the performance of these duties. Communication by radio, telephone, and direct conversation is necessary. The communications among control personnel, by any or all of the cited methods, should be of the highest quality. This is not always the case today in the presence of current aircraft noise levels. The means for controlling these adverse effects of noise are known, but they sometimes cost a great deal.

Men Outside the Air Base or Airport

These are people whose residences, businesses, and places of recreation and relaxation are outside the confines of the air facility. We separated them into two groups: one group, people affiliated with air operations; the second group, those having no such affiliations. The problems acoustic energy creates for both groups are identical. The separation of the groups is justified only because there may be a difference in the *general attitude* of the group members toward air operations that is related to their association or nonassociation with such operations.

Examination of current spatial relations between air bases or airports and communities indicates that the acoustic energy from air operations *will not:* (1) cause mechanical damage to the human body or any of its parts; (2) produce pathological changes in any body part or system, such as the ear, any sensory receptor, or the nervous system; (3) cause reversible temporary loss of hearing; (4) induce functional disability (nausea, ataxia, reduced precision of manual acts). Let me repeat. The effects just mentioned *WILL NOT OCCUR* among people outside an air base as a result of exposure to NOISE from air operations.

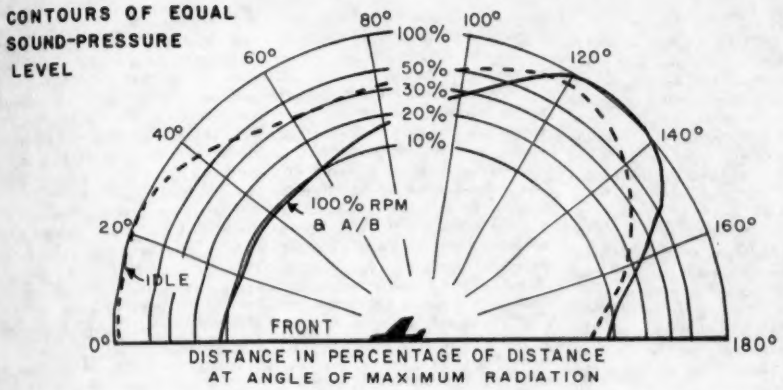
Air operations, sometimes ground operations, and, more frequently, flight operations generate a sufficiently high noise level in areas near the air base to cause interference with communication. The interference caused by flight operations lasts only a few seconds during the passage of each aircraft. This disturbance is, therefore, related to the frequency of flights. Data are available for estimating the level of speech interference and evaluating the impairment of communication that will result. If a particular speech interference level is selected, reasonable estimates can be made as to the distance that must separate the air operation and a residence to insure that the selected speech interference level is not exceeded.

Three other responses of people to acoustic energy are significant with respect to persons outside an air base. These responses are: (1) arousal of general annoyance or dissatisfaction; (2) arousal of apprehension or fear; (3) initiation of antagonistic activities toward the source. In our general discussion of human responses to acoustic energy we stressed the complexity of these reactions and the almost complete lack of information about them. These responses almost certainly interact. Interference with speech communication may also be an element in generating some of them. The limited and preliminary studies that have been conducted to date have no more than suggested the complexity of these responses and perhaps defined some of the important contributing factors.

One engineering approach[9] to the problem of community reaction to noise in general has attempted to estimate the response of people by considering a complex of operational and other factors. The applicability of this approach to problems created by noise from air operations has not been established. It may be a useful interim engineering tool.

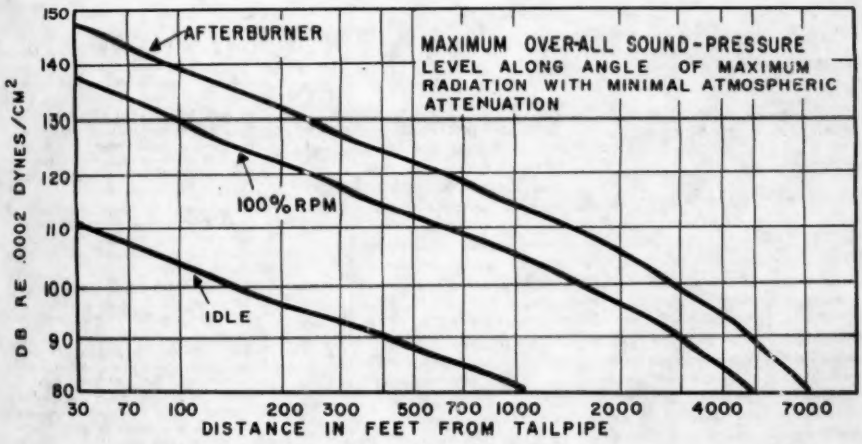
These complex responses of people to noise must be recognized as important in connection with air operations. Likewise, the necessity for additional research on these problems must be recognized.

FIG. 7. Noise characteristics of fighter aircraft.



OVER-ALL LEVELS AT SPECIFIC MAINTENANCE POSITIONS

POSITION	ENGINE OPERATION		
	IDLE	100% RPM	A/B
COCKPIT (CANOPY OPEN)	99 DB	118 DB	124 DB
CREW	104 DB	128 DB	133 DB



We Can Now . . .

We can now estimate noise levels near aircraft and state their most significant effects on maintenance and other operating personnel. We can provide protection for maintenance personnel when the problems result from effects on the ear. In some instances the protection is marginal, particularly in view of the time spent in the noise.

We can estimate the effects of aircraft noise on communications, for personnel inside aircraft, and for those engaged in ground operations. In many, perhaps all, cases we can control noise so that the communication required for conducting essential operations is adequate. This may be very costly, and in some cases the quality will be marginal.

We can now state that four types of human responses are not significant for people outside the air base. These are: (1) mechanical damage to the body; (2) pathological change; (3) temporary hearing loss; and (4) disturbance to locomotion, muscle control, nervous mechanisms and similar functions.

We Cannot Now . . .

We cannot now adequately specify NON-auditory effects of very intense noise on people.

We cannot now properly evaluate the essential elements of the complex human responses that are important for evaluating the effects of noise on people outside air bases.

We cannot reduce the noise produced by flight operations to those levels that all operating personnel consider to be desirable.

A Glance into the Future

In the immediate future, aircraft engine power will be increased. The acoustic power output will also increase. Estimates of this increase have been made. Our typical power plant operated with an afterburner produces 100 kw of acoustic power. Future engines may produce about 2000 kw of acoustic power. This is a power level increase of 13 db, an acoustic power increase of about twenty times. This would also mean a sound-pressure level increase of about 13 db in the direction of maximum radiation.

In opposition to these acoustic power increases, there are now known methods for reducing the source level that may result in a power level decrease of 6 to 8 db. This would mean in the future a remaining power level increment of 5 to 7 db. However, the noise reduction methods cited alter the directivity pattern of the noise radiated and may introduce a decrease in the sound pressure in the direction of maximum radiation of 15 db or more. The power is radiated in a less directional manner, and there is not an equal increase in radiated power in any other direction.

The net result is: Noise power will increase. If our best *source noise reduction* methods are applied to the new engines and improved somewhat, the noise problem for people located at moderate and large distances from the aircraft will remain about what it is today. Some reduction in sound-pressure levels may result. There is some hope that new methods for *source reduction* of noise output can be developed that may result in slightly more reduction in the noise levels in areas surrounding an air base.

We Must Do . . .

We must do the following things now:

1. We must approach the problems pertaining to acoustic energy from air operations and its effect on people using the acoustic energy concept.

a. This concept states the problems in terms of the interactions among: acoustic energy sources; acoustic energy transfer paths; acoustic energy receivers.

b. The use of this concept means considering not only detailed technical problems, but all of the operational problems simultaneously with the technical questions.

c. The concept implies that solutions to these problems will be obtained only through the efforts of an integrated technical team.

2. We must apply to the maximal extent all of our current knowledge, both technical and operational, so that the effects of aircraft noise and vibration on people are reduced as much as possible.

3. We must increase substantially our efforts to develop practical means for effective *source noise output* reduction.

4. We must accelerate the development of man-made transfer media for the control of noise from ground operations, with special emphasis on the development of less costly, longer-lasting devices that weigh less and are thereby at least semi-mobile.

5. We must approach the several problems pertaining to complex responses of people, in which areas we now have practically no information, in a serious, thoughtful manner. Emotional approaches are useless and confusing.

As an interim means of estimating probable responses of people located outside air facilities, we should apply the proposed method mentioned in the previous discussions to determine that *IT IS or IS NOT* a suitable tool for use in connection with problems pertaining to the complex responses of people to noise from air operations.

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Dr. PARRACK. When we are considering actual research and development on this problem, we have to use techniques or tools that come from both the physical sciences, or engineering sciences, and from the biological sciences, and we have to use these simultaneously.

For example, it is not possible to predict the effect of the sounds in a given environment, aeronautical or other, on man until we are able to describe that sound in physical terms. And we require physical methods for making this description.

We also require physical methods in many instances for actually measuring the responses of the man. And we have to have all the other tools that measure factors that relate to the physiological and psychological and other responses, so that our efforts must combine and use tools from both technical areas, physical sciences, and biological sciences.

Now, in order to have at any time a realistic analysis of a specific problem or to develop a program where you have all of these diverse tools in use and where the problem has components from both the physical science and biological sciences area, you have to have some kind of integrating concept.

We have used the same concept that was described yesterday, the acoustic energy systems concept, remembering that the components were: (1) sources, (2) transmission paths, and (3) receivers.

I would like to pass over the detailed part of my discussion pertaining to that, by saying, one, that it was discussed yesterday, and, secondly, it is described much more fully in the same article I cited a few moments ago.

I would then like to state that in the latter part of 1952, using this concept, the Air Force analyzed its problems in this area. Along with the analysis of the problems, using the acoustical energy concept, it analyzed its existing programs.

Now, it was found that these programs did pertain to acoustic energy sources, to acoustic energy transfer media or paths, and to acoustic energy receivers.

It was also found that by and large the programs in existence at that time were adequately balanced in these areas and that the estimated cost per year, at the end of 1952, was approximately $1¼ million.

Now, this analysis of the existing programs and of the problems at this time was the first detailed study the Air Force had made of its efforts to control aircraft and missile noise.

Because this analysis became the basis of an expanded program that was initiated in 1953, I have included in annex 1, which is available for the record, a report of the analysis conducted in the latter part of 1952 and which contains a short history of the problem area, a description of the programs in effect at that time, an outline of the future programs the Air Force definitely had planned at the time, and a brief description of the technical areas included in that program.

Again, as a result of this analysis—in the latter part of 1952—during the first half of 1953 the USAF initiated a single integrated research program on aircraft and missile noise and made a single coordinator and director responsible for it.

The general objectives of the program initiated were to achieve by doing research in the relevant physical and biological sciences the development of a system. And this system was to make it possible

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to adequately control human exposure to acoustic energy, that is, the noises and vibrations we have been talking about, and vibration; second, to assure levels of acoustic energy that would be acceptable to humans in their normal environments, working or living environments; and, third, to prevent damage to structures by controlling the acoustic energy levels to which they were exposed; and, fourth, to provide or develop general criteria relevant to aircraft and missile noise that would be suitable for the planning of our air bases.

Now, these 1953 requirements for the program or a description in completely technical terms of the tasks that had to be accomplished are outlined in annex 2, which has been made available for the record.

Along with this we have an annex 3, which goes into detail—in a technical way—on the program initiated in early 1953, which is also available for the record.

Now, the program that was initiated in 1953 and 1954 on aircraft and missile noise, its generation, its propagation, its effects and its control, expanded each year from 1953 through 1957. The effort placed on this program was maximal about 1957. The reorientation of the Air Force research and development programs that occurred in 1958 has decreased the effort on this program each year since that time.

This program of the Air Force has been fully coordinated within the Air Force by a special technical coordination office. Coordination with other military services has been achieved by utilizing the services of the Armed Forces, National Research Council's Committee on Hearing and Bio-Acoustics, known as CHABA. Coordination with NACA, with other nonmilitary governmental agencies and industry has been achieved in the past by the Technical Coordination Office and by use of the NACA Special Subcommittee on Aircraft Noise, which was inactivated about the time NASA was formed and activated.

Now, the program that we have carried out has produced certain results. I would like to try to summarize some of the major results. I will summarize these results under the three areas that we have talked about, that is, with respect to sources, transfer paths, and receivers.

In the area pertaining to acoustic energy sources, and here you will recall we used primarily physical science techniques, we have the following results:

One, the basic mechanisms by which jet-type propulsion systems generate noise have been determined and described. However, additional research on these mechanisms may be required in connection with the most advanced rocket engines.

Second, it has been shown that jet and rocket engine sources cannot be designed or modified to achieve major reductions of the acoustic energy, and that is true at least up to the present date. Future engines of another category, such as have been mentioned here this morning, that are not now in use, may raise a ray of hope, but I have long since learned that it is highly undesirable to be overly optimistic about what these new things will do until we have actually developed them and tried them out in operational situations.

Third, it has been demonstrated in cooperation with NACA and industry that airborne suppressors cannot produce major reductions in jet engine noise without introducing reductions in aircraft performance that are not acceptable to the Air Force.

Fourth, the acoustic energy output, under all of the important operating conditions of the sources, of current U.S. Air Force propulsion systems have been determined and described quantitatively.

Fifth, methods have been developed for estimating the acoustic energy output of propulsion systems using data that define their design parameters, and these estimates can be made before the prototype systems have been built. Except for the most advanced rocket motors, these methods have been experimentally verified to a large extent.

Sixth, principles have been discovered and applied in developing methods for estimating acoustic energy levels on the ground that result from the flight of aircraft overhead.

Seventh, "Aerodynamic generation of noise," at the surface of aircraft has been studied and the mechanisms of generation determined except for flight at high mach numbers.

Eighth, theories of the generation of shockwaves at supersonic speeds have been developed, and these theories have been experimentally substantiated in a general way except for flight at very high mach numbers.

Now, turning to the area pertaining to the transfer paths—and again the primary tools here are in the physical sciences—the Air Force program has resulted in (1) a basic understanding of sound propagation in the air, the atmosphere, (2) the developing principles for using atmospheric attenuation of acoustic energy as a means of noise control, (3) an understanding of the influence of weather variables and very limited methods for predicting their influence on noise propagation in practical situations around an air base. Better meteorological prediction techniques are probably necessary before these methods can be improved.

Fourth, the basic principles upon which to base the design of ground runup noise suppressors have been elucidated, but satisfactory engineering application of these principles to ground runup noise suppressors has not been achieved.

Fifth, engine test cell noise control treatments that can achieve any desired degree of noise reduction have been developed, but they are applicable only when no consideration is given to cost.

Additionally, in the area pertaining to receivers—first, I would like to consider structural elements as receivers, the Air Force program has been able (1) barely to define the problems of the effect of acoustic energy on complex structures such as aircraft wings. This, of course, is the sonic fatigue problem.

(2) We have been able to gather data upon which to base improved design of electronic components, resistant to the effects of acoustic energy. However, the responses of complex electronic systems (that is, systems of these components) to high acoustic energy levels, have not yet been adequately described and quantified.

Finally, looking at man as a receiver of this acoustic energy or noise, we use a combination of physical science tools and biological science tools.

The Air Force has produced data and corollary information to support:

(1) Formulation of criteria for long-duration exposures to operational noise environments that assure preservation of normal hearing.

(2) Tentative criteria for short-duration exposures of man to similar noise environments are available.

(3) The development of improved personally worn noise protectors has been achieved and these assure preservation of the hearing function of our maintenance personnel.

(4) A tentative evaluation and estimation of the nonauditory effects of intense sound on man has been made. However, many new data are required here to formulate adequate criteria.

(5) Preliminary interpretation of the way in which the mechanical properties of the body tissues influence entry of acoustic energy into the body and its propagation throughout the body, have been determined, but we do not know enough about impulsive applications of acoustic energy and its effects on the human body.

(6) The development of preliminary empirical methods for estimating the response of community residents to aircraft and missile noises have been developed, but further validation of these methods is required and they need to be supported by relevant new data obtained by new psychological, psychophysical, psychosociological, sociological, economic, and like research.

(7) The development of general and special methods for estimating the effects of aircraft and missile noise on voice communication are available.

Now, in a general way, the basic and applied research program that has resulted in the accomplishments I have just enumerated has cost the Air Force approximately the following amounts of money:

Fiscal year 1953 and 1954, $1¼ million; 1955 and 1956, 1957 and 1958, approximately $2 million; 1958 and 1959, it is of the order of $1 million.

Now, in addition to this direct basic and applied research work, there has been engineering development work carried on; engineering studies have provided useful information in this area. This is estimated to have cost approximately half of the amount given for each of those years. So that the total amount over this 7-year period is of the order of $15 million, exclusive of those amounts of money that were used for special facilities, such as the Bio-Acoustic Research Laboratory at Wright-Patterson Air Force Base, other buildings of this type, and the instrumentation.

Now, instrumentation is no small matter. It is my estimate that the instrumentation in the Bio-Acoustic Research Laboratory at Wright-Patterson Air Force Base and its mobile facilities which it uses around the country, cost of the order of $1½ million to $2 million, and like sums for other sets of instrumentation used in the program.

Having completed this period of our program, I would like to look at the situation now and to summarize very briefly a few items that we may call requirements of the present day or an inventory of the things that need to be done now and through the future.

First, we need detailed information about the sound fields of advanced propulsion systems. This need includes the need for detailed descriptions of the "near field" around these systems and detailed phase correlation of the sound fields from them, over very large areas. This information is needed primarily for use in connection with the sonic fatigue studies.

Second, we need the exploration of new mechanisms of acoustic energy generation associated with nuclear propulsion systems and perhaps with other new systems that may appear.

Third, we need to measure and evaluate the general effects of low-frequency sounds of the reentry and blastoff operations with rockets or missiles.

Fourth, engineering developments are needed to incorporate available data into a design for an effective ground runup suppressor.

Fifth, study of the long-distance propagation of low-frequency sound in relation to missile operation is needed.

Sixth, evaluation of the effects on man of very low-frequency sound and low-frequency vibration, and the impulsive application of acoustic energy in any form is still to be accomplished.

Seventh, determination of the effects on man of very long-lasting exposure to sound, as will occur with operators of satellite and space vehicles, is also needed.

Eighth, we must evaluate the significance of the physiological and behavioral changes in man induced by exposures to low-level noise, but low-level noise that lasts over very, very long time periods.

Ninth, one of the most important things still to be done is the evaluation of the significant psychophysical, psychological, sociological, economic—and many other factors that are the basis of the adverse community response to aircraft and missile noise.

That completes my statement.

The CHAIRMAN. Thank you very much, Doctor. You have set up for yourself a real program there, as I judge from your narration of important requirements.

I think your statement does show a great deal of attention to this problem and a comprehensive program, and I want to commend the Air Force for having made the progress that it has in this area, which promises to be extremely important in the future.

I want to ask you a few things regarding your statement. Now, is there such a thing as noise in space?

Dr. PARRACK. External to a vehicle?

The CHAIRMAN. External to a vehicle.

Dr. PARRACK. I think the answer is "No," sir.

The CHAIRMAN. Is there, then, a possibility of eliminating noise as far as the occupant of a space vehicle is concerned?

Dr. PARRACK. Again the answer is "No," because we have to have some kind of system for maintaining an environment in which the man can survive.

Unfortunately, all of these systems so far, unless we have genii of the type we have never seen before, these systems will in the future produce noise, and man will be in a noisy environment.

The CHAIRMAN. You must have an environment surrounded by atmosphere for any man in a space vehicle?

Dr. PARRACK. That is right.

The CHAIRMAN. That, in itself, produces a noise within the atmosphere.

Dr. PARRACK. It provides a medium for the transmission of the sound waves and the equipment that maintains this environment in which one can live generates the noise and radiates it into this gaseous medium.

The CHAIRMAN. Is noise transmitted in any way through space? For instance, are there portions of the mechanism of the space vehicle separated by space from the occupant of the vehicle?

Dr. PARRACK. If it has no mechanical connections and if we are in those regions of space which you could consider an almost absolute

vacuum, then there would be no noise transmission, but if components are connected mechanically, there will be noise.

The CHAIRMAN. So, if you have two vehicles, then there could be no communication between the two?

Dr. PARRACK. Not directly by sound or voice.

The CHAIRMAN. What do you mean, "not directly"?

Dr. PARRACK. I mean, you would have to use a system of communication such as radio; then at both ends of the system you would have noise.

The CHAIRMAN. You could use radar?

Dr. PARRACK. Yes, or radio.

The CHAIRMAN. Could you use radio communication?

Dr. PARRACK. Yes, the usual type of radio system.

The CHAIRMAN. How is that?

Dr. PARRACK. Yes, sir; you could transmit across the space between vehicles.

The CHAIRMAN. You could use radio. Isn't that sound communication?

Dr. PARRACK. At the input, in the environment where the man lives it is sound, but it is an electromagnetic wave propagation process across the space between the two vehicles.

The CHAIRMAN. You can use radio.

Dr. PARRACK. You can use that, and you can use television.

The CHAIRMAN. You can use television?

Dr. PARRACK. Yes, sir.

The CHAIRMAN. But he couldn't talk on a telephone, could he, from one vehicle to another?

Dr. PARRACK. Radiotelephone?

The CHAIRMAN. Yes.

Dr. PARRACK. Radiotelephone, yes, and if he wanted to string a line between the two vehicles, the usual kind.

The CHAIRMAN. I doubt that that would be attempted.

At any rate, he is going to be plagued with noise as long as he has atmosphere around him in the vehicle.

Dr. PARRACK. That is my opinion, sir.

The CHAIRMAN. What are the major problems the Air Force has in the noise field?

Dr. PARRACK. I covered it in a very general way in my statement. If that is sufficient—the problems can be defined technically if you like, and they can be defined operationally.

The CHAIRMAN. I think you have covered that pretty well.

You are not able to give us much information on high mach aircraft?

Dr. PARRACK. High mach?

The CHAIRMAN. High mach. That is above the speed of sound.

Dr. PARRACK. That is right, for certain of the technical areas I mentioned, sir.

The CHAIRMAN. Now, we need to do a lot more work in that respect.

Dr. PARRACK. I think this is right.

The CHAIRMAN. Now, any questions?

Mr. Bass?

Mr. BASS. Doctor, can you tell me what the present policy of the Air Force is in preventing property damage due to sonic booms?

Dr. PARRACK. Well, the present policy is—wherever possible to conduct the operations in such a way that the sonic booms will not

occur under conditions which produce a ground pressure wave sufficient to cause damage. That is the policy.

Mr. BASS. I come from southern New Hampshire, where we have sonic booms being experienced every day. They come from planes based on Westover Airfield. I have many complaints that I have received from people who claim property damage to their houses as a result of sonic booms.

I have here a letter from General Fisher, dated January 27, 1959, in regard to this problem, and he states in his letter that the Air Force has a policy of forbidding pilots to fly supersonically below 35,000 feet.

Does that correspond with your information?

Dr. PARRACK. I think that officially, and for general use, the number is 30,000 feet at present.

Mr. BASS. In other words, pilots can fly supersonically at 30,000 feet or more over an inhabited area?

Dr. PARRACK. Essentially the instruction is this: that supersonic flights, flight at supersonic speed will not be initiated below, will be conducted above and will be terminated at altitudes above 30,000 feet, except over water areas where the limitation is 10,000 feet.

These, I believe, are the actual numbers in use and prescribed by the general regulation. Specific higher altitudes may be prescribed for specific operations.

Mr. BASS. Is it your opinion, Doctor, that an airplane flying at 30,000 feet, at a supersonic speed, cannot cause any damage whatsoever to a building on the ground?

Dr. PARRACK. It is not my opinion that this is universally so. Also, put it the other way round, it is also my opinion that this is not universally so.

This (the damage capability) depends on the characteristics of the aircraft, its size, how much above minimum supersonic speed it is flying, and a number of other factors, including such things as peculiar conditions within the atmosphere between the aircraft and the ground.

Mr. BASS. So that if I understand you correctly, under certain conditions it is possible for a plane flying 30,000 feet or more to cause damage, property damage on the ground?

Dr. PARRACK. I would have to ask you, if you want me to answer this in absolute terms, to define what you mean by property damage.

Mr. BASS. Well, I would be glad to. I mean by that, cracks in the plaster, breaking windows, structural damage to buildings.

Dr. PARRACK. All right. I will accept that it is possible, for certain types of aircraft that are available now, with their flight-speed capabilities, flying at 30,000 feet, to produce damage to glazing, but it is unlikely or I would say, highly improbable, that they will damage plaster at this altitude. And I am sure, at least in terms of structural damage, as defined by structural engineers, structural damage will not occur at all, if the flights are conducted at an altitude of 30,000 feet and above.

Mr. BASS. So that what you are saying, Doctor, is that planes flying supersonically at 30,000 feet or more cannot cause structural damage to buildings on the ground; is that correct?

Dr. PARRACK. That is what I said; yes.

Mr. BASS. But under certain conditions which you say occur very rarely, it is possible for planes flying at those altitudes, 30,000 and above, to break windows or cause plaster cracks, but very rarely?

Dr. PARRACK. I said that at 30,000 feet I think it is very unlikely that there would be plaster damage. At 30,000 feet, I would expect some kinds of aircraft under certain operational conditions to damage glazing to a limited extent. Incidentally, the higher above 30,000 feet you go, the less the chances of causing any of these damages.

Mr. SISK. Would my colleague yield for just a moment?

Mr. BASS. Yes; certainly.

Mr. SISK. Doctor, is it possible for an aircraft flying at supersonic speeds—and I am not setting any particular height—to kill, for example, a flock of turkeys or a flock of chickens or something of this kind?

The CHAIRMAN. In flight? [Laughter.]

Mr. SISK. The Air Force has a claim pending, I happen to know, in my own district at the present time, for a substantial flock of chickens, which, according to the owner as well as neighbors and others, were destroyed, feathers blown off of them, and so on, by a sonic boom from an Air Force plane.

Now, at what altitude would you anticipate such a plane must have been flying in order to create that type of situation?

Dr. PARRACK. It should have been on the ground. [Laughter.]

Seriously, that is—it would have to be a few feet from the animals.

Mr. SISK. But do you take the position that this could not have occurred?

Dr. PARRACK. I take the position at the moment that I do not have all of the facts in this case.

Mr. SISK. I am not going to hold you to try a court case here, Doctor, because I am not naming any specific instance.

But this, I am sure, is not the first case of this kind that has come up. Frankly, the Air Force has said, Well, this is impossible.

First, they say: We didn't have a plane in that area.

This is the typical deal. The Air Force and the Navy didn't have a plane there. It seems to be passing the buck, kind of like the shell game, that you get on this sonic boom.

I have no criticism of the forces. If I were flying the plane, I would hope that I wasn't in that particular spot, myself.

The CHAIRMAN. Does the doctor tell us that we can't kill ducks in flight with an airplane that way?

Dr. PARRACK. If you hit them, I think you could. Excuse me. Let me go just a little further.

I don't know the details of the kind of thing you talked about, unless you can describe a particular case. However, it is well known that flocks of turkeys and even flocks or bevies of chickens and so on, exposed to any unusual kind of disturbance run together, run into the fences, run together and scratch and tear each others' feathers off.

I don't know whether this is part of the story. We frequency found on the farm, that we had several dead chickens when we got to market because they crowded up in corners of the cases, so we had to design cases to keep them separated.

This is one possibility. Without having further information about this case, I can't give you a more reasonable answer.

Mr. BASS. Doctor, referring back to sonic booms, I also have in my hand an Air Force information sheet, entitled "Sonic Boom Information Sheet."

Are you familiar with that particular document?

Dr. PARRACK. I have been familiar with certain issues of the document called "Sonic Boom Information Sheet" or "Sonic Boom Fact Sheet," I don't remember the exact title. What is the date of this one?

Mr. BASS. This particular sheet was enclosed in the letter that I referred to, dated January 27, 1959. Is it the same, now?

Dr. PARRACK. I can't answer absolutely, but I think it probably is very similar, if not the same at the present time.

I am not positive on that. I can get this information for you, but I don't know it absolutely at this time.

Mr. BASS. Mr. Chairman, I would like to request that this sheet that I have in front of me be inserted in the record at this point.

The CHAIRMAN. If there is no objection, it is so ordered.

Mr. BASS. Together with this letter from General Fisher.

The CHAIRMAN. Is the letter in reference to sound?

Mr. BASS. Sonic booms.

The CHAIRMAN. If there is no objection, it is so ordered.

(The documents above referred to are as follows:)

DEPARTMENT OF THE AIR FORCE,
Washington, January 27, 1959.

Hon. PERKINS BASS,
House of Representatives.

DEAR MR. BASS: I refer to your inquiry regarding sonic booms and damages from jet aircraft in the Monadnock area of New Hampshire.

It has been determined that the primary source of sonic booms in New Hampshire and throughout the New England area is the F–104 Starfighters located at Westover Air Force Base, Mass. The F–104 is the fastest aircraft in America's air defense network and will be required to perform this important mission until its role can be taken over completely by guided missiles. It has been placed at Westover to defend the important New England area.

With the advent of planes like the F–104, sonic booms can no longer be avoided. Supersonic flight is a design characteristic inherent in the plane. Although it can cruise below the speed of sound, it must fly supersonically when performing an intercept mission. These high speeds are never attained until the plane reaches an altitude of 35,000 feet. Yet, even from high altitude the shock wave generated by supersonic speed will strike the ground. The plane need not be diving or stunting to cause this effect. As long as the plane is traveling faster than the speed of sound the shock wave extends outward in all directions. Therefore, as the F–104 makes its supersonic dash to intercept an unidentified aircraft, it drags a continuous sonic boom along with it. We have found that under proper atmospheric conditions this shock wave may extend as far as 30 miles on either side of the flight path with disturbing intensity. The sharp explosive sound tends to create fear and apprehension among individuals on its path and has caused many misconceptions of what the sonic boom is capable of doing. Extensive testing has proven that the intensity of the shock wave from high altitude dissipates below the point of creating damage to structures. Additional information on this phenomenon is summarized in the inclosed fact sheet.

The Air Force is concerned about public disturbances and has imposed restrictions designed to minimize the sonic boom. The F–104 pilots are forbidden to fly supersonically below 35,000 feet. The extensive testing and training required to prepare men and machines for combat are conducted away from populated areas whenever possible. Because of vast distances traveled while flying supersonically and the large area covered by the shock wave, it has become impossible to avoid all our citizens.

Sincerely yours,

W. P. FISHER,
Major General, USAF, Director, Legislative Liaison.

Sonic Boom Information Sheet

A question and answer summary of the sonic boom phenomenon and its accompanying noise and damage potential.

1. What is a sonic boom?

Basically, sound is a wave of various pressures and lengths hitting the ear. They are the results of any surge of energy. Generally, they might be compared to the ripples created by a rock thrown into a still pond. Ordinary conversation is actually a series of pressure wavelets pulsating against the ear, much as the ripples of water gently slapping the shore of the pond. By these standards, an explosion is in effect a strong pressure wave pushed outward by the sudden release of energy. Descriptive of these strong waves of pressure is their name—shock waves or as we will also say herein "sonic booms" or "booms."

2. How does it act?

If they were visible, shock waves would resemble a shallow dish as they attach to the airplane at the exact speed of sound. Later, as the plane's speed increases, the waves sweep back at sharp angles until they form the cone shape of a wide funnel. Thus the boom travels through space as a wave. Unlike the numerous ripples of water to which it was compared, there is only one, at the most possibly two ripples in our shock wave. As this wave reaches the ground traveling approximately with the speed of sound, it finds its passage obstructed by all kinds of obstacles, trees, buildings, cars, people, and so forth. It possesses only a small finite amount of power to begin with. As it passes through the air and over the ground, it is continually being robbed of its energy by friction in the air and on the ground and by the work it has to do in going around and over obstacles.

Whenever an increase in pressure occurs at the eardrum, we have a sound. Therefore, anyone in the path of the cone of high-pressure air will hear a sound at the time the cone passes him. Since the aircraft which is generating the cone is traveling at a very high rate of speed and since the high pressure is produced almost instantaneously, the observer will hear a very sharp loud crack which sounds much like a thunderclap.

As the shock wave strikes an obstacle such as a house, it passes over and around the structure pressing on it from all directions. However, it reflects off the front wall of the house like a wave reflecting off a seawall and the pressure on the front wall then becomes about twice the original or free-stream pressure.

3. What is the pressure magnitude of these sounds?

The loudest thunderclap recorded generated a pressure of around one-half pound per square foot. The loudest sounds normally found in a boiler factory are around 1 pound per square foot. The difference between the boiler factory noise and a thunderclap is that the boiler factory noise is continuous and that the thunderclap occurs suddenly, often without warning, and lasts only a fraction of a second. The boiler factory noise produces a pressure wave twice as great as the pressure produced by the thunderclap, yet it is not particularly frightening since it is an expected noise.

In tests, where airplanes have dived from 35,000 feet and pulled out at 25,000 feet scientists have measured pressure no greater than 5 pounds per square foot on the ground. Even when the aircraft descends to 10,000 feet before pulling out of its dive the recorded pressure did not reach 10 pounds per square foot. Rarely are faster-than-sound operations carried out at altitudes lower than 20,000 feet. This would mean that sonic boom pressures no greater than 5 pounds per square foot are expected to be observed on the ground. However, these pressures are still 10 times greater than the recorded strongest thunderclap. A sonic boom, with a pressure 10 times stronger than a thunderclap is readily understood to be a startling phenomenon.

4. What pressure is required to cause structural damage?

Scientists and engineers observing the effects of shock waves generated by atomic explosions have never observed structural damage to the flimsiest of test structures at pressures less than 70 pounds per square foot. Applying simple arithmetic, this is 65 pounds more than the pressure normally observed from a sonic boom. The behavior of dwellings and industrial buildings of block, brick, and frame construction tested by nuclear explosions have revealed that it takes free stream on the order of 150 to 300 pounds per square foot to cause structural damage in buildings of these types. Even the strongest sonic boom pressure recorded by scientists at this time cannot cause pressure even approaching this magnitude.

In fact, the strongest measurement scientists have ever been able to get was on a mountaintop from an aircraft flying 280 feet away. The recorded pressure was 33 pounds per square foot. Some structural damage to a weak building might possibly occur when the free-stream pressure gets this high and we certainly could expect plaster cracks. It is highly unlikely, however, that any jet pilot would operate an aircraft at sonic or supersonic speeds at an altitude of 280 feet except under extremely unusual conditions.

5. Why won't a sonic boom produce structural damage?

Newton's famous "Second Law of Motion" states, in effect, that a body stays in a state of rest or continues to move with constant velocity in a straight line unless some force is exerted on it. This is the basis of a very important fact. If a building or any of its components are to be moved or set vibrating, they must be set in motion by the force applied to the outside of the house.

Applying the principle of Newton's law and some accepted engineering methods it is possible to evaluate the effect of forces described on a wood-stud wall with a plaster inside surface. Such walls generally run between 8 and 10 feet in height and are constructed from 2 by 4 studs 16 inches on centers.

Without considering strength contributed by the sheathing, siding and plaster, it is assumed that the wood stud takes all the load which in this case will be considered as 5 pounds per square foot. As an example, consider a vertical strip in the middle of the wall, 16 inches wide, to represent the loading on a single stud. On a single stud the load per stud is 5 by 10 by 1⅓ or 67 pounds. The shear at the top and bottom is 33½ pounds; the maximum tension in the stud at the middle is 200 pounds per square inch of stud.

Most codes call for at least three 12-penny nails to fasten each stud to the plate. These nails provide the shear resistance. Compare the forces described to the shear strength of three 12-penny nails, which for most wood is at least 1,000 pounds per square inch. The conclusion is obvious.

The same kind of calculations can be made on block or brick walls; shearing force versus shearing resistance and tensile strength due to bending versus tensile resistance of mortar. The results are again equally obvious.

A great deal is heard about plaster cracks being caused by sonic booms. Most building authorities say in order to prevent plaster cracks, the deflection at the middle of the beam or girder should not exceed one three-hundred-and-sixtieth of the span length. So, as long as a 10-foot stud does not bend more than one-third inch at the middle from its normal position, the wall plaster will not crack. By calculation, the deflection of the stud wall under load, again assuming the stud alone takes all the load, will be about one-third of the deflection required to crack the plaster.

Calculations of this kind can be extended to various elements of the house, such as roofs, side walls, porches, and other types of construction. They will all demonstrate what has been shown above: that sonic booms normally fall far short of causing sufficient load to crack walls, roofs, plaster, floors, walks, and so forth. All this can be summed up very simply; the whole house including the roof receives a very quick and light squeeze by the pressure of a sonic boom.

6. Do sonic booms create significant vibrations on a structure?

There is a peculiar scientific fact that enters into the misunderstanding of vibrations. Scientists have observed and proven that people observe things by perceptions that are false.

For example, it was reported that the structures were being shaken violently and the ground was jumping up and down an inch or two when large aircraft were flying overhead. Even the scientists who went out to investigate admitted to this feeling. Yet, measuring the pressures with the most sensitive instruments available indicated no movement—slamming a screen door drove the measuring instrument completely off the scale.

The fact is that false perceptions of movement are received because the sense organs in the skin require only pressures measured in a millionth part per square inch to cause a sensation of movement. It is, therefore, difficult for people to believe that there is no vibration of the earth; that what they feel is only a false perception.

As for the other fact about vibration, many people are familiar with the principle of vibration in harmonics and the feeling given by vibration of interior walls and ceilings on its own plane. Most structural elements of houses have natural frequencies of vibration ranging from 5 to 20 and even 40 cycles per second. The sonic boom, when it reaches the ground from an elevation of 10,000 feet or more, is equivalent to a frequency of about five or less cycles per second. Thus, the

elements of the house want to vibrate much more rapidly than the boom. It is known that when a slowly vibrating force is applied to a structure which has a much higher rate of vibration, the structure cannot sense the vibration period of the force and behaves just as if the applied force were steady. The structure is "not in resonance" especially if the force is only applied one time. It, therefore, has a tendency not to vibrate by its harmonics. While the latter may and in some cases do occur, they are imperceptible in magnitude.

7. Do sonic booms create significant vibrations on the ground?

Soils, even tight clay, are considerably looser than most building materials and as a result it becomes much more difficult to make the soil mass vibrate. When the mass of soil in and around a house down to the level of the footings is considered and an attempt is made to move or vibrate such a mass with the puny force of a sonic boom, it appears completely out of reason. Scientists dealing with nuclear explosions have found that even good-sized air bombs which produce many, many times the pressure of a sonic boom have very little, if any, effect on the ground or on structures such as walks, pavements, pipes, footings, etc. It may be said with confidence, therefore, that no sonic boom is going to break up concrete walks or drives or break up basement walls or floors.

8. What effect will the sonic boom have upon windows and doors?

No mention has been made of openings in a structure. Sonic boom effect upon windows and doors must be considered. First, consider the windows. The sash, frame, mullions, etc., because of the materials of which they are built, are all elements which are more than strong enough to resist the relatively minute force of the boom. The glass, however, is another matter. Glass is in one sense a strong material; however, it is relatively brittle compared to other building materials when used in thin sheets.

The methods by which it is manufactured are apt to produce internal "lockedup" stresses. The methods of installation and the workmanship employed are apt to produce additional stresses due to its being bent ever so slightly when installed. Thus, a sharp blow, even though a light one, may shatter the glass. This is not to say that sonic booms will always break windows, because they definitely will not. Experiments with large explosions have shown that ordinary window glass will break at free stream pressure ranging from 18 to 70 pounds per square foot. This is much greater than the force produced by by booms and supports the idea that glass breakage is much more apt to occur because of the stress induced during manufacture and during installation.

Doors, with the exception of glass areas are much stronger than necessary to resist boom forces. Weak points are the locks and the hinges. If the lock is loose fitting, the impact of the boom may be sufficient to jar the opening and cause the door to bang against the wall. Under this condition, or if the door is partly ajar, the hinges might pull loose or cause a split in the doorjamb.

9. Will the sonic boom damage masonry walls or plaster?

It is well known that bricks, blocks, plaster, and mortar do not have any measurable ability to creep. When laid up into walls or ceilings, they also have locked-up stresses which are caused by such things as the hydration (curing) of the mortar or plaster, shrinkage due to the drying out of mortar or plaster or the effect of expansion and contraction between hot summer and cold winter temperatures. Since these materials have no "give" they either stand all these force combinations indefinitely or fail after about one or two seasonal cycles. It may, therefore, be said that these brittle structures adjust themselves to their environment very rapidly by cracking very early in their life. No one will deny that if the boom forces were appreciable, brick, block, or plaster stressed close to the point of failure by the combination of locked-up and seasonal forces might be overloaded; but since the boom force on a structural element is far less than that of a good stiff windstorm or, in many cases less than that of a healthy boy jumping on the floor, it is difficult to see how a wall could remain poised just at the point of failure for any length of time without being tipped in by other more frequent forces.

On at least two separate occasions the Air Force has attempted to test sonic boom damage. In each case small, light, dwelling-type buildings were put up and the interiors furnished with the usual household items, including mirrors, bric-a-brac, dishes, etc. These structures were subjected to booms, both diving and level flight over a wide range of altitudes and speeds. Not a single case of even dish or window breakage was observed. While not scientific in nature, these demonstrations afford a good basis for saying that the sonic boom does not cause structural damage unless it occurs at very close distances to the structures.

10. Why can't aircraft creating sonic booms be readily identified?

The characteristics of jet aircraft engines dictate flight at higher altitudes than aircraft with reciprocating engines. Normal jet operations are carried out at altitudes of 20,000 feet or above. These operating altitudes are becoming increasingly higher as new aircraft of greater performance enter the Air Force inventory. The normal high cruising speed of jet aircraft, coupled with high altitude operations make it possible for an aircraft to be a considerable distance away from the scene of the boom it creates. An aircraft creating a sonic boom may cause people on the ground to hear the boom 30 to 40 miles away from the path of the aircraft. Atmospheric conditions play a significant part in the propagation of these sound waves.

Although air defense identification zones are in existence, flights originating within one of these zones are naturally considered to be friendly and receive no further attention from the standpoint of identification. Air defense identification zones are established to provide for positive identification of aircraft entering the zone from an outside departure point.

11. How does the sonic boom affect the citizen?

When people hear this very loud sound which is roughly 10 times the intensity of a loud thunderclap, they immediately get the idea that there must have been damage caused and they start looking. The find crack after crack that they feel certain was not there before the boom. They are sure of it because they live in that house every day and they have never seen them. Of course, they have never seen them; principally because they were not looking for them. It is amazing, but true, that the eye sees many things that never register on the conscious mind and, therefore, are not seen. Seeing such damage for the first time after a boom, the citizen immediately assumes it was caused by a sonic boom and requests payment for damage.

12. What is the Air Force policy on alleged sonic boom damage?

It is the policy of the Air Force that whenever its operations cause damage prompt payment of fair amounts for such damage shall be accomplished. At the same time, the Air Force has a tremendous obligation to the taxpayers and the citizens of this country to expend each dollar appropriated in a proper manner.

To be certain that both of these obligations are met—to pay when damage is caused and to deny payment when it is not caused—a very thorough investigation of the alleged damage must be accomplished. Generally this investigation, conducted in the light of the facts previously explained, results in the decision that a sonic boom could not have caused the damage claimed. This is not to say that the Air Force doubts the sincerity of the claimants' belief, but factual evidence which science has made available to us must be used in determining the authenticity of a claim for such damage.

13. How does the sonic boom affect the Air Force?

The Air Force is charged with the tremendous task of providing aerial protection to this country and insuring continued freedom in consonance with our American way of life.

To carry out this task, we must maintain a ready combat capability in the most superior air vehicles technology can provide. More and more supersonic aircraft are entering the operational inventory of the Air Force. These aircraft, capable of supersonic speeds in all flight altitudes, are creating an increasing number of sonic booms all over the country. This phenomenon, occurring without warning, produces a startling, explosive sound which causes the public to react unfavorably toward the Air Force. Responsive to the public which it defends, the Air Force continuously attempts to carry out its missions with the least possible disturbance to the people. However, the world's best Air Force cannot be maintained if its pilots must fly all missions at subsonic speeds and then someday, when the chips are down, fly their aircraft on actual missions for the first time at supersonic speeds.

14. How does this affect the aircraft manufacturer?

The aircraft manufacturer is affected by public opinion in much the same manner as the Air Force. The manufacturer is under contract to the Air Force to produce aircraft with performance capabilities which will enable the Air Force to carry out its missions. Research, development, and testing of new aircraft are vital and necessary functions in the production of aircraft that will keep us a step ahead of any aggressor. Supersonic flight is a normal part of this development and production process.

The manufacturer, however, is forced by public opinion to perform supersonic aircraft testing farther and farther away from his plant in order to develop such aircraft for the defense of this country. This, in turn, increases the cost to the taxpayer for the final product.

15. How does this affect the people of the United States?

The people expect the best possible protection for their homes, families, and country. The Air Force is providing 24-hour-a-day, 365-day-a-year protection in all kinds of weather. This responsibility is accepted with the full knowledge of the cost of failure. Air Force personnel are citizens of this country dedicated to accomplishing this job of vital importance. When friction exists between an Air Force base and the community near that base, Air Force people are made to feel unwelcome. Being human, this naturally is resented, and many airmen leave the service at the first opportunity and seek employment in other fields where they are not regarded as a nuisance. This results in the requirement for a continuous retraining program to maintain an adequate force and costs the taxpayer billions of dollars yearly.

The loud sound of the sonic boom, admittedly, is a startling one. Every effort is made by the Air Force to spare the citizens of this country from being startled by this disturbance to the greatest possible extent. However, as long as the need exists for continuous air surveillance of our country to prevent possible foreign intrusion, sonic booms may be heard from time to time in all parts of the country.

The sonic boom is assurance that the Air Force is on the job and is carrying out its responsibility to train, equip, and maintain a force capable of assuring continuous aerial protection of this country from attack.

Mr. BASS. Would it be possible, having inserted this material in the record, for you to supply, after you have had a chance to look it over, to supply for the record your opinion as to whether or not based on present-day information, you feel that this information as to sonic booms is correct?

Dr. PARRACK. You are speaking now of the information in the document?

Mr. BASS. Yes, sir.

Dr. PARRACK. I believe so.

Mr. BASS. One other question. In this document on page 6 there is a statement saying that any claim for damage, of course, will be considered, and I am quoting, after investigation:

> Generally, this investigation, conducted in light of the facts previously explained, results in the decision that the sonic boom could not have caused the damage claimed.

This has resulted, Doctor, as far as I can make out, in every single claim for damage being turned down, at least in my area, because it is impossible after the sonic boom has occurred to prove, as I understand it, that a plaster crack or a broken window has been caused by a sonic boom or some other disturbance.

Is that not correct?

Dr. PARRACK. It is difficult to prove it.

The CHAIRMAN. If the gentleman will yield, is there anything in reference to the climate or the atmosphere in New England that would make sound more damaging? [Laughter.]

Dr. PARRACK. At a particular hour and day atmospheric conditions may make it more damaging or less damaging. It will change within 15 or 20 minutes. I used to live there, myself. But in a general way, and seriously——

The CHAIRMAN. Yes, seriously.

Dr. PARRACK. No, there is not a significant difference as far as the usual average atmosphere is concerned.

Mr. BASS. It really is impossible, not difficult; it is impossible to prove any claim against the Air Force with this policy in effect, is it not, as I have described it?

Dr. PARRACK. Unfortunately, I didn't understand all that you read.

Mr. BASS. Well, the hour is getting late. Perhaps we will leave it this way: After you have had a chance to look this over, and bearing my questions in mind, would you supply for the record your considered answer to these points that I have raised?

Dr. PARRACK. All right, sir.

(The information requested is as follows:)

The document cited and entered in the record is an attempt to make an elementary explanation in simple terms of a very complex phenomenon. The factual data given is correct. However, certain assumptions were made in interpreting the data on the responses of residential structures. Recent studies have cast some doubt on the validity of these assumptions and a review of the entire problem is being made. This review will consider the newer, larger, and faster flying aircraft and the strength of the shock waves they generate in supersonic flight. Changes may be required in any new issue of the "Sonic Boom Information Sheet" and at present, the document is not being distributed.

Mr. SISK. Mr. Chairman.

The CHAIRMAN. Mr. Sisk?

Mr. SISK. I would like to pursue this sonic boom situation a little bit further. Were you here yesterday, Doctor, when we had some charts in which it showed the area that would be affected where a sonic boom would be heard as a plane flying at supersonic speeds passed over? I think it showed a 50-mile area which theoretically at any given point, would be a circular area of 50 miles.

Now, my question is this: Is the attitude of the plane in flight, by that I mean, if it is diving or climbing or flying level, have any specific effect at a specific area on sonic booms?

In other words, to what extent are sonic booms concentrated in a given small area, or dissipated over a wider area depending on the height and attitude of the airplane?

I don't know whether I make my question clear. I hope so, but is it something that is generally dissipated or is it concentrated by the attitude of the airplane to where it actually strikes a given area? If it happens to hit a house almost like a directed sound wave.

Dr. PARRACK. I think I have your question. Let me try: First of all, I saw that figure that you saw yesterday only from the back, but I think I know it. [Laughter.]

I would translate or I would interpret that figure a little bit differently. In the part that you were talking about, I believe it showed an altitude of some figure, 70,000 feet or thereabouts. I am not sure of the exact altitude. What, in fact, I think the figure showed was that for 25 miles on either side of the ground trace of that aircraft, over whatever distance it traveled, let it be between New York and Los Angeles, or some other distance, there would be a streak on the ground 50 miles wide or 25 miles either side of the ground track in which sonic boom sound pressure waves would be detected, that is, they would be hearable.

The human ear could detect them. That is if I remember the chart correctly. And there was a very much smaller area at a certain point in the flight profile where they showed a small circle, I think, indicating that there might be certain possible damage to glazing and so on.

In other words, it would be a more intense wave. Now, one of the areas in which, perhaps, there should be more work in connection with the sonic boom phenomena is in trying to numerically determine the effects that changes of direction, a slight dive, a slight climb, a slight turn, have on the strength of the pressure wave. It may be that some of this information has already been obtained very recently but I have not had access to it.

Mr. SISK. I yield.

Dr. PARRACK. But in general, it is true that such maneuvers may alter the strength of the wave. The important question is whether the alteration is sufficient to make them seriously more damaging or less damaging.

Mr. SISK. I yield to my colleague, Mr. Bass.

Mr. BASS. Thank you.

Doctor, suppose I am a property owner and my windows are broken and some plaster cracks occur as a result of a sonic boom, which you have said is possible under certain circumstances, and I put in a claim for damage with the Air Force. How can I under present Air Force policy satisfy the Air Force that this was caused by sonic boom and get my claim allowed? What must I show to satisfy them, the investigators?

Dr. PARRACK. Well, this gets into the realm of the Claims Division of the Judge Advocate General and I would prefer not to try to answer this in detail now, but I would also be willing to try to get for you and for the record a reasonable answer, with their support.

Mr. BASS. Would you do that, please?

(Dr. Parrack nods.)

(The information requested is as follows:)

THE SONIC BOOM

1. What is a sonic boom?

Basically, sound is wavelengths of various pressures hitting the ear. They are the results of any surge of energy. Generally, they might be compared to the ripples created by a rock thrown into a still pond. Ordinary conversation is actually a series of pressure wavelets pulsating against the ear, much as the ripples of water gently slapping the shore of the pond. By these standards, an explosion is no more than a strong pressure wave pushing the sudden release of energy. Descriptive of these strong waves of pressure is their name—shock waves.

2. How does it act?

If they were visible, shock waves would resemble a shallow dish as they attach to the airplane at the exact speed of sound. Later, as the plane's speed increases, the waves sweep back at sharp angles until they form the cone shape of a wide funnel. Thus the boom travels through space as a wave. Unlike the numerous ripples of water to which it was compared, there is only one, at the most possibly two ripples in our shock wave. As this wave reaches the ground traveling with the speed of sound it finds its passage obstructed by all kinds of obstacles, trees, buildings, cars, people, etc. It possesses only a small finite amount of power to begin with. As it passes through the air and over the ground it is continually being robbed of its energy by friction in the air and on the ground and by the work it has to do in going around and over obstacles.

Whenever an increase in pressure occurs at the eardrum we have a sound. Therefore, anyone in the path of the cone of high-pressure air will hear a sound at the time the cone passes him. Since the aircraft which is dragging the cone is traveling at a very high rate of speed and since the high pressure is concentrated in a very small volume, the observer will hear a very sharp loud crack which sounds much like a thunderclap.

3. What is the pressure magnitude of these sounds?

The loudest thunderclap recorded generated a pressure of around one-half pound per square foot. The loudest sounds normally found in a boiler factory

are around 1 pound per square foot. The difference between the boiler factory noise and a thunderclap is that the boiler factory noise is continuous and that the thunderclap occurs suddenly, often without warning, and lasts only a fraction of a second. The boiler factory noise produces a pressure wave twice as great as the pressure produced by the thunderclap yet it is not particularly frightening since it is an expected noise.

In tests, where airplanes have dived from 35,000 feet and pulled out at 25,000 feet scientists have measured pressure no greater than 5 pounds per square foot on the ground. Even when the aircraft descends to 10,000 feet before pulling out of its dive the recorded pressure did not reach 10 pounds per square foot. Rarely are faster than sound operations carried out at altitudes lower than 35,000 feet. This would mean that sonic boom pressures less than 5 pounds per square foot are expected to be experienced on the ground. However, these pressures are still 10 times greater than the recorded strongest thunderclap. A sonic boom, with a pressure 10 times stronger than a thunderclap is readily understood to be a startling phenomenon.

4. What pressure is required to cause structural damage?

Scientists and engineers observing the effects of shock waves generated by atomic explosions have never experienced structural damage to the flimsiest of structures at pressures less than 70 pounds per square foot. Applying simple arithmetic, this is 65 pounds more than the pressure normally experienced from a sonic boom. The behavior of dwellings and industrial buildings of block, brick, and frame construction tested by nuclear explosions have revealed that it takes free-stream pressure on the order of 150 to 300 pounds per square foot to cause damage ranging from plaster cracks to wall and roof cracks. Even the strongest sonic boom pressure recorded by scientists at this time cannot cause pressure even approaching this magnitude. In fact, the strongest measurement scientists have ever been able to get was on a mountain top from an aircraft flying 280 feet away. The recorded pressure was 33 pounds per square foot. This is not sufficient pressure to cause structural damage. It is unlikely that any jet pilot would operate an aircraft at sonic or supersonic speeds at an altitude of 280 feet except under extremely unusual conditions.

5. Why won't a sonic boom produce structural damage?

Newton's famous "Second Law of Motion" states, in effect, that a body stays in a state of rest or continues to move in a straight line unless some force is exerted on it. This is the basis of a very important fact. If a building or any of its components are to be moved or set vibrating, they must be set in motion by the force applied to the outside of the house.

Applying the principle of Newton's law and some accepted engineering methods it is possible to evaluate the effect of forces described on a wood-stud wall with a plaster inside surface. Such walls generally run between 8 and 10 feet in height and are constructed from 2 by 4 studs 16 inches on centers. Without considering strength contributed by the sheathing, siding, and plaster, it is assumed that the wood stud takes all the load. As an example, consider a vertical strip in the middle of the wall, 16 inches wide, to represent the loading on a single stud. On a single stud the load per stud is 5 times 10 times 1⅓ or 67 pounds. The shear at the top and bottom is 33½ pounds; the maximum tension in the stud at the middle is 200 pounds per square inch of stud. Most codes call for at least three 12-penny nails to fasten each stud to the plate. These nails provide the shear resistance. Compare the forces described to the shear strength of three 12-penny nails, which equals 100 times 3 equals 300 pounds and the tensile resistance of the stud, which for most wood is at least 1,000 pounds per square inch. The conclusion is obvious.

The same kind of calculations can be made on block or brick walls; shearing force versus shearing resistance and tensile strength due to bending versus tensile resistance of mortar. The results are again equally obvious.

A great deal is heard about plaster cracks being caused by sonic booms. Most building authorities say in order to prevent plaster cracks, the deflection at the middle of the beam or girder should not exceed one-three hundred and sixtieth of the span length. So as long as a 10-foot stud does not bend more than one-third inch at the middle from its normal position, the wall plaster will not crack. By calculation, the deflection of the stud wall under load, again assuming the stud along takes all the load, will be about one-third of the deflection required to crack the plaster. This applies only to plaster in sound condition. It is certainly conceivable that already defective plaster could be triggered by even the slightest

pressure and therefore fall or prior existing cracks could be aggravated by slight pressure.

Calculations of this kind can be extended to various elements of the house, such as roofs, sidewalls, porches, and other types of construction. They will all demonstrate what has been shown above: that sonic booms normally fall far short of causing sufficient load to crack walls, roofs, plaster, floors, walks, etc. The total of all this can be summed up very simply. A whole house including the roof receives a very quick and light squeeze by the pressure of a sonic boom.

6. Do sonic booms create significant vibrations on a structure?

There is a peculiar scientific fact that enters into the misunderstanding of vibrations. Scientists have observed and proven that people observe things at times by perceptions that are false. For example, it was reported that the structures were being shaken violently and that the ground was jumping up and down an inch or two when large aircraft were flying overhead. Even the scientists who went out to investigate admitted to this feeling. Yet measuring the pressures with the most sensitive instruments available indicates no movement; slamming a screen door drove the measuring instrument completely off the scale. The fact is false perceptions of movement are received because the sense organs in the skin require only pressures measured in a millionth part per square inch to cause a sensation of movement. It is difficult for people to believe that there is no vibration of the earth but is only a false perception. As for the other fact about vibration, many people are familiar with the principle of vibration in harmonics and the feeling given by vibration of interior walls and ceilings on its own plane. Most structural elements of houses have natural frequencies of vibration ranging from 5 to 20 and even 40 cycles per second. The sonic boom is equivalent to a frequency of about 3 or less cycles per second. Thus the elements of the house want to vibrate much more rapidly than the boom.

It is known that when a slowly vibrating force is applied to a structure which has a much higher rate of vibration, the structure cannot sense the vibration period of the force and behaves just as if the applied force were steady. The structure is "not in resonance" especially if the force is only applied one time. It, therefore, has a tendency not to vibrate by its fundamental note or any of its harmonics. While the latter may and in some cases do occur, they are imperceptible in magnitude.

7. Do sonic booms create significant vibrations on the ground?

Soils, even tight clay, are considerably looser than most building materials and as a result it becomes much more difficult to make the soil mass vibrate. When the mass of soil in and around a house down to the level of the footings is considered and an attempt is made to move or vibrate such a mass with the puny force of a sonic boom, it appears completely out of reason. Scientists dealing with nuclear explosions have found that even good-sized air bombs which produce many, many times the pressure of a sonic boom have very little, if any, effect on the ground or on structures such as walks, pavements, pipes, footings, etc. It may be said with confidence, therefore, that no sonic boom is going to break up concrete walks or drives or break up basement walls or floors.

8. What effect will the sonic boom have upon windows and doors?

No mention has been made of openings in a structure. Sonic boom effect upon windows and doors must be considered. First, consider the windows. The sash, frame, mullions, etc., because of the materials of which they are built, are all elements which are more than strong enough to resist the relatively minute force of the boom. The glass, however, is another matter. Glass is in one sense a strong material; however, it is relatively brittle compared to other building materials when used in thin sheets. The methods by which it is manufactured are apt to produce internal "lockup" stresses. The methods of installation and workmanship employed are apt to produce additional internal stresses due to its being bent ever so slightly when installed. Thus a sharp blow, even though a light one, may shatter the glass. This is not to say that sonic booms will always break windows because it definitely will not. Experiments with large explosions have shown that ordinary window glass will break at free stream pressure ranging from 18 to 70 pounds per square foot. This is much greater than the force produced by booms and supports the idea that glass breakage is much more apt to occur because of the stress induced during manufacture and during installation.

Doors, with the exception of glass areas are much stronger than necessary to resist boom forces. Weak points are the locks and the hinges. If the lock is loose fitting the impact of the boom may be sufficient to jar the opening and cause

the door to bang against the wall. Under this condition, or if the door is partly ajar, the hinges might pull loose or cause a split in the doorjamb.

9. Will the sonic boom damage masonry walls or plaster?

It is well known that bricks, blocks, plaster, and mortar do not have any measurable ability to creep. When laid up into walls or ceilings, they also get locked-up stresses which are caused by such things as the hydration (curing) of the mortar or plaster, shrinkage due to the drying out of mortar or plaster, or the effect of expansion and contraction between hot summer and cold winter temperatures. Since these materials have no "give" they either stand all these force combinations indefinitely or fail after about one or two seasonal cycles. It may, therefore, be said that these brittle structures adjust themselves to their environment very rapidly by cracking very early in their life. No one will deny that if the boom forces were appropriate, brick, block, or plaster stresses close to the point of failure by the combination of locked-up and seasonal forces might be overloaded; but since boom force on a structural element is far less than that of a good stiff windstorm or, in many cases less than that of a healthy boy jumping on the floor, it is difficult to see how a wall could remain poised just at the point of failure for any length of time without being tipped in by other more frequent forces. This presents a good basis for saying that the sonic boom does not cause structural damage.

10. Why can't aircraft creating sonic booms be readily identified?

The characteristics of jet aircraft engines dictate flight at higher altitudes than aircraft with reciprocating engines. Normal jet operations are carried out at altitudes of 35,000 feet or above. An aircraft generating a sonic boom may cause people on the ground to hear the boom 20 to 40 miles away from the path of the aircraft. Atmospheric conditions play a significant part in the propagation of these sound waves.

Although air defense identification zones are in existence, aircraft operating within one of these zones once identified friendly, receive no further attention. These zones are established to identify aircraft entering the zone from an outside departure point.

With the normal high cruising speed of jet aircraft, coupled to high altitude operations, it is possible for the aircraft to be considerable distance away from the scene of the boom it generates. This is further complicated by the factthat, except for certain required position reports en route, a jet aircraft may not be known to be in a designated area at a certain time.

11. How does the sonic boom affect the citizen?

When people hear this sound 10 times the intensity of a very loud thunderclap, they immediately get the idea that there must have been damage caused and they start looking. They find crack after crack that they know were not there before the boom. They are sure of it because they live in that house every day and they have never seen them. Of course they have never seen them; principally because they were not looking for them. It is amazing, but true, that the eye sees many things that never register on the conscious mind and, therefore, are not seen. Seing such damage for the first time after a boom the citizen immediately assumes it was caused by a sonic boom and requests payment for damage.

12. What is the Air Force policy on alleged sonic boom damage?

It is the policy of the Air Force that whenever its operations cause damage prompt payment of fair amounts for such damage shall be accomplished. At the same time, the Air Force has a tremendous obligation to the taxpayers and the citizens of this country to expend each dollar appropriated in a proper manner.

To be certain that both of these obligations are met; to pay when damage is caused and to deny payment when it is not caused, a very thorough investigation of the alleged damage must be accomplished. Generally this investigation, conducted in the light of the facts previously explained, results in the decision that a sonic boom could not have caused the damage claimed. This is not to say that the Air Force doubts the sincerity of the claimants belief, but factual evidence which science has made available to us must be used in determining the authenticity of a claim for such damage.

13. Does the Air Force pay for sonic boom damage?

Under the provisions of the Military Claims Act (10 U.S.C. 2733) the Secretary of the Air Force may pay claims not in excess of $5,000 for damage caused by the noncombat activities of the Air Force.

Supersonic flight is considered a noncombat activity of the Air Force and consequently damage caused by an Air Force sonic boom is payable under that statute.

14. For what type damage will the Air Force pay?

As set forth previously the scientific data presently available to the Air Force indicates that, normally, the following can result from a sonic boom generated below 45,000 feet.

1. Window and plate glass may be broken. As a result of this glass breakage, adjacent property, such as drapes, can also be damaged.
2. Light bric-a-brac may be shaken from shelves and broken.
3. Damage to loosely latched doors may occur.
4. If there is extensive glass breakage caused by a low-level sonic boom, then there is the possibility of aggravating existing plaster cracks and damage to defective plaster. (In such situations, 50 percent of the cost of repairing the plaster is considered adequate.)
5. Structural damage, which is defined as damage to foundations, floors, load-bearing walls, etc., cannot be caused by a sonic boom.
6. Direct physical injury to an individual cannot be caused by a sonic boom.
7. In exceptional circumstances depending on temperature, speed, profile of flight as well as numerous other factors, damage might be caused in excess of 45,000 feet. This is of course rare.

15. What does the Air Force do when a sonic boom is generated or a complaint received?

When a complaint is received by an Air Force base that a sonic boom has caused damage the base claims officer immediately makes inquiry of all Air Force, Navy, Marine Corps, Air National Guard, and civilian manufacturers normally engaged in supersonic flying within a reasonable radius on the site of the alleged damage, to determine whose aircraft was responsible for the boom. This inquiry also solicits the altitude and profile of any relevant supersonic flight, and all other details which might indicate the severity or other characteristics of the boom.

The local base claims officer then conducts an investigation of the damaged property to determine the types and amount of damage, and the probable cause thereof. This investigation is normally made with the assistance of a qualified engineer and a photographer. The engineer submits a complete and detailed description of the damage and an analysis of its cause. Photographs are taken at the direction of the engineer and the claims officer.

Complainants are usually advised of the above-stated Air Force policy as to what types of damage are ordinarily expected from sonic booms. The purpose of stating this policy is to enable the complainant to decide intelligently if they wish to obtain extensive and, possibly, expensive appraisals in view of the likelihood that such administrative claims may not be payable.

16. How many sonic boom claims has the Air Force paid?

The following is a statistical summary of sonic boom claims processed by the Air Force for fiscal years 1956 through 1959. It is noted that the number of claims and amounts disapproved is considerably different than the number of claims and amounts approved. This is understandable since it is usual for any type claim to be presented in an amount in excess of what is expected by the claimant as a just award. In the case of the sonic boom this factor is further affected by a genuine misunderstanding by the claimant as to exactly what damage was in fact caused by the sonic boom.

Fiscal year	Total numbers	Total amount claimed	Number approved whole or part	Amount approved	Number disapproved	Amount disapproved whole or part
1956	36	$12,220.03	21	$1,913.71	15	$10,306.32
1957	372	157,100.45	286	18,907.85	86	138,192.60
1958	522	196,215.66	235	39,519.06	287	156,696.60
1959	327	228,326.18	91	7,970.57	236	220,355.61
Total	1,257	593,862.32	633	68,311.19	624	525,551.13

The CHAIRMAN. Mr. Sisk?

Mr. SISK. I realize we are late, but I have one more point with reference to a statement you have made and I have heard this discussed before, of the relative reduction in power of jet engines through various types and methods of silencers or various types of nozzles which are used to reduce noise levels.

Is there a fairly constant reduction in percentages as the noise ratio goes down with reference to whatever type of equipment may be used to reduce the sound?

Is there a fairly constant decrease in power ratio or are there actually noise reducers that will not decrease power? As I understand, the aircraft companies, manufacturers particularly in California, consider it a great problem; any time they reduce noise it immediately reduces power, of course, in some instances more than others.

Dr. PARRACK. You are now speaking about in-flight suppressors?

Mr. SISK. That is right.

Dr. PARRACK. Used for the purpose of attempting to reduce the jetstream generated noise from turbojet engine propelled aircraft, is that right?

Mr. SISK. That is right. Or also for takeoff purposes. For instance, where they have to use the afterburners. To what extent can they reduce that takeoff noise without reducing substantially their ability to get into the air with heavier equipment?

Dr. PARRACK. I don't know the exact figures on the reductions. The last numbers I heard stated for performance amounted, for the takeoff operation, to something of the order of 5 or 10 percent, but I have said here—and I don't intend that it be applied to any agency other than the Air Force—is that any reduction in performance capability, considering the type of operation we have to carry out and the kind of equipment we use for this, any decrement of performance whatsoever is not acceptable. And this would have to be a very, very small, fractional percentage in terms of overall performance to be accepted.

Mr. SISK. In other words, the Air Force cannot afford to reduce its operating efficiency or its power in any sense? In other words, they can stand the noise better than they can stand the reduction in operating efficiency?

Dr. PARRACK. I don't know whether we can. We have to essentially. As a matter of fact, we are continually pressing for greater power.

The CHAIRMAN. Will the gentleman yield? I think you in your statement referred to that as being extremely expensive.

Dr. PARRACK. Pardon me.

The CHAIRMAN. I think in your statement you referred to suppression of noises as being extremely expensive.

Dr. PARRACK. I gave a very specific condition, and this was a facility for controlling the noise from the ground operations of a turbojet engine removed from the aircraft and in a test cell, a particular building or enclosure.

The CHAIRMAN. Thank you.

Mr. SISK. I want to ask you this: I notice in 2 years here you had expenditures of about $2 million a year, 1956 and 1957. And you dropped in 1958 and 1959 to $1 million. Why did you cut your

expenditures in this research? You haven't accomplished the results or the objectives by any means; have you?

Dr. PARRACK. Well, I think the best answer I can give to this is that if you look generally at research conducted by governmental agencies, all of them, concerned with aeronautical operations, about that time they all took a new look and sort of hitched their vision on a star, so to speak, even though an artificial one, and I would say that the decreased research on noise is primarily a result of the reorientation of all research programs and the limitations on the total sums of money available for doing work.

The CHAIRMAN. If there are no further questions from the members, I would like to recognize Captain Silberstein to ask two or three questions. He is our able counsel.

Mr. DADDARIO. I just have one question.

The CHAIRMAN. All right.

Mr. DADDARIO. Is there any deteriorating effect from the continued operation of airplanes over a specific flight pattern day after day on material in houses? Taking Mr. Bass' problem—and I have some of them in my own area—could an airplane flying at 30,000 feet day after day over the same house deteriorate the plaster in that house to the point where eventually the sonic impulses would have it crack?

Dr. PARRACK. You are now referring to the sonic boom phenomena, only, not noise, not sounds?

Mr. DADDARIO. Well, the combination of all of them put together.

Dr. PARRACK. At 30,000 feet? I think that we actually do not have that kind of information about the response properties of typical residential structures to vibration, or applications of vibratory forces of any kind. They have simply never been studied in this way. The closest approach to it would perhaps be the studies that have been directed toward learning what wind velocities they will tolerate. If we were to make a comparison from this, then the effects you described are very unlikely. Now, quite apart from the glazing problem, you see, you are talking about fatigue.

Mr. DADDARIO. I am talking about fatigue in the structures.

Dr. PARRACK. On the basis of what we know about the effects of winds, and so on, fatigue is extremely unlikely in my opinion.

Mr. DADDARIO. That is all, Mr. Chairman.

The CHAIRMAN. Captain Silberstein?

Captain SILBERSTEIN. Dr. Parrack, would you say that homes or apartment buildings that were built in close proximity to elevated railways were subjected to vibration over long periods of time? There is probably more information there than there is in the aircraft problem with respect to vibration?

I don't know whether there were any claims against elevated railways in the old days, but as I recall in my youth, in reading stories about these buildings, the people that lived in them were subjected to quite a bit of vibration and annoyance.

Dr. PARRACK. Captain, are you now concerned with the fatigue problem?

Captain SILBERSTEIN. Yes.

Dr. PARRACK. Or the noise problem with people? I am not sure which we are on.

Captain SILBERSTEIN. The fatigue problem with respect to cracked plaster and foundations.

Mr. DADDARIO. If you are directing it to my last question, the thing I am concerned with is the combination of all of these things, because if there is a claim, it is a combination of both the vibrations and sonic impulses that bring all of this together.

How do you finally bring it down to what does the damage, how do you separate one from the other, is really the problem.

The CHAIRMAN. Why don't you first take up the fatigue problem and then the sonic boom problem?

Dr. PARRACK. Returning to the captain's question and assuming he is talking about the fatigue problem, I don't know that any data have been taken on this, nor am I familiar in any detail with the types of claims that were made. I do know that in many places at the time these elevated structures were put up, the owners, at least, were given some monetary compensation for some of the difficulties produced by the presence of the elevated system.

Judging from the age and appearance, the age of some of the houses in the vicinity of some of the el's that used to be in the city of New York when I lived there, I would say there couldn't have been a very serious fatigue problem. That is the only basis I have. I have no data.

The CHAIRMAN. What is the sonic boom problem?

Dr. PARRACK. Well, I think the real fact is that in the mechanical engineering field or structural engineering field, we do not have data about structures such as are used, the structural designs such as are used in residences, when they have been subjected repeatedly to a force of this kind—upon which to base an answer.

I simply don't have any data or any basis for judging. I only say this, it would depend upon the repetition rate and I think that the repetition rate would have to be much more frequent than it is ever likely to be under any kind of airway that we will use in this country. I just can't visualize getting the aircraft this close together.

The CHAIRMAN. The answer is you don't have the data on it?

Dr. PARRACK. That is right. And the absence of the data is primarily in the field of engineering that deals with the properties, the responses of residential-type structures to impact-type pressure waves. To the best of my knowledge, very little has been done here.

Captain SILBERSTEIN. Doctor, suppose an aircraft is flying at 60,000 feet. It went into a dive that is maintained over a reasonable period of time. Would it not focus the sonic boom on a given point on the ground for a greater length of time and, therefore, inflict more damage than if the aircraft was in level flight at 30,000 feet?

Dr. PARRACK. Are we pulling out and still remaining supersonic at 30,000 feet or going subsonic?

Captain SILBERSTEIN. No; you are still supersonic, but you are level. In other words, you focused the sonic boom because you were in a dive.

Dr. PARRACK. There is some evidence that in the dive and particularly in a maneuver in the dive like this, that there may be some strengthening of the wave. It usually is not very great. And it is probable that the wave present at the time of pullout would continue in the direction of the aircraft before pullout and would strike the ground, but it isn't, I think, likely, unless there are unusual atmospheric conditions, that it will be increased significantly as a result of

the propagation. It is only the initial increase in strength at the source. This is usually very little.

The CHAIRMAN. Mr. Riehlman?

Mr. RIEHLMAN. The doctor has referred on several occasions here this morning to certain damage done. He has used the word "glazing." Could you define the word?

Dr. PARRACK. When I speak of glazing, I simply mean the glass in houses.

Mr. RIEHLMAN. Just glass?

Dr. PARRACK. Yes.

The CHAIRMAN. Plexiglas, or anything of that sort?

Dr. PARRACK. Well typically it refers to window glass. It could mean Plexiglas.

Mr. BASS. Not the breaking of glass, but just glass?

Dr. PARRACK. Well glazing as I understand it, is putting glass into the windows of a house and it is also referred to as the glass used in the construction of a building and that is the sense in which I am using it. I can say window glass if you like, just as well.

Mr. RIEHLMAN. No, this isn't anything to take lightly. We are definitely interested in knowing whether or not it referred to glass or glazing of some other kind.

Dr. PARRACK. No; it refers to glass.

Mr. RIEHLMAN. You used the word as something that the committee is definitely interested in. Plaster is something, too, that we are interested in. Of course, you might have a glazing over plaster. There are other areas that might be glazed over.

I understand that it is used in the term of glass, but we just want to be sure that we have the definition defined properly as to what you say it is.

Dr. PARRACK. When I have used "glazing," I intended glass, and when I intended plaster, I have said plaster.

Mr. RIEHLMAN. All right.

The CHAIRMAN. Colonel, do you have any questions?

Colonel TURNER. One question I would like to ask the doctor.

Doctor, the atmospheric conditions affect the impact from the sonic boom. Is that right? The varying atmospheric conditions will determine how strong it is at different times?

Dr. PARRACK. Principally, I think that the thing most likely to occur in the propagation path is that the wave may be changed in its direction, and if it is bent, the path may become longer or shorter. If it is a shorter path, it will be somewhat stronger. If it is a longer path, it will be weakened.

It is also possible, but there hasn't been much evidence of it in the data I have seen, to have certain conditions which tend to concentrate or pull together waves that are separate at the beginning and maybe have them reinforce each other.

I haven't seen much evidence of this. It is primarily the change in path length.

The CHAIRMAN. Any further questions?

Mr. McDonough?

Mr. MCDONOUGH. Would you compare a sonic boom with a similar sound on Earth produced under some other conditions? I mean produced by some other manmade sound.

Dr. PARRACK. Well, I would have to answer this, I think, in this way: In my experience so far, people who hear their first sonic boom always say it is an explosion, and they start looking in the direction of the most likely thing that they think might explode, such as an oil storage tank, a gas storage tank, or something of this kind.

In terms of my own experience, and thinking of the variety of the characteristics of these sounds, as I have heard them, at various times under various conditions, they have the characteristics of anything from very distant rolling thunder, a distant summer thunderstorm, to a very sharp crack of the thunder from a very nearby flash or discharge of lightning.

Mr. MCDONOUGH. You mean the thunder is about the only thing you can compare a sonic boom with?

Dr. PARRACK. Or an explosion of certain types of ground equipment.

The CHAIRMAN. Any further questions?

(No response.)

The CHAIRMAN. If not, Doctor, we want to thank you very much for your testimony this morning.

(The prepared statement of Dr. H. O. Parrack, together with annex I, II, and III, follows.)

NOT FOR PUBLICATION UNTIL RELEASED BY THE COMMITTEE ON SCIENCE AND ASTRONAUTICS

STATEMENT OF DR. H. O. PARRACK
TECHNICAL COORDINATOR, AFR&D PROGRAM
(NOISE AND VIBRATION)
BEFORE THE COMMITTEE ON SCIENCE
AND ASTRONAUTICS
HOUSE OF REPRESENTATIVES
WASHINGTON, D. C.

AIRCRAFT AND MISSILE
NOISE PROBLEMS

Mr. Chairman and Members of the Committee:

It is a pleasure to appear before you this morning to present the Air Force position relative to the problems of sound associated with our aircraft, missiles and rockets. These sounds will be "noise" or, more specifically, "acoustic noise" whenever they interfere with something man desires to do. When strong enough, sounds can damage parts of the human body and certain mechanical structures. Weaker sounds completely stop some human activities and make other activities ineffective.

We can easily understand why our aircrews and groundcrews shun any environment which may weaken the structure of their airplane or damage their bodies. These same persons deem any environment that interrupts their conversation, rest, relaxation, sleep or operational activity as undesirable if not hazardous. The sounds from aircraft or missile propulsion systems are strong enough to produce all of these effects on men and structures. The magnitude of this effect depends upon the distance between the source and the receiver - man or structure. These sounds are called noises because of their undesirable effects and the term used - noise or sound - depends on the interpretation by each man in his normal environment. The aircrew or missile-man interprets engine sounds as a necessity for mission completion. To the community resident, engine sound is noise because it interferes with or completely stops routine activities in his home or business.

In summary, sounds are noises and create problems when, (1) they produce undesired effects on man, (2) they alter the plans of man, (3) they interfere with the timing of activities of man, (4) they reduce the effectiveness of operations by man or, (5) they evoke interactions and

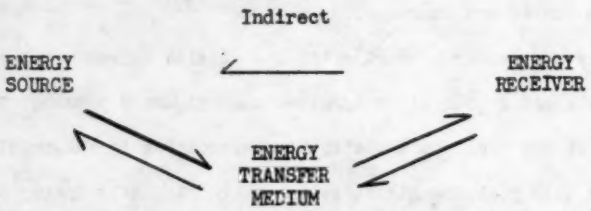
conflicts among groups of men. These concepts are discussed in an article, "Noise, Vibration and People," published in Noise Control, Volume 2, No. 6, dated 6 November 1956. (Copies are available for the record).

In actual practice, research, development and engineering to control the effects of aircraft, missile or rocket noises must be oriented in the fields of biological and physical sciences simultaneously. One cannot investigate the effects of noise on man within a given environment until a quantitative evaluation of the sound fields of that environment is completed. The physical tools to generate, control and measure sound fields are needed before the biological effects on man can be related to the physical qualities of sound as causative factors. When complex human responses (such as community response to aircraft noise) are under study, we need as a minimum a combination of techniques and methods for evaluating the physical, psychological, psycho-physical, sociological and economic factors concerned.

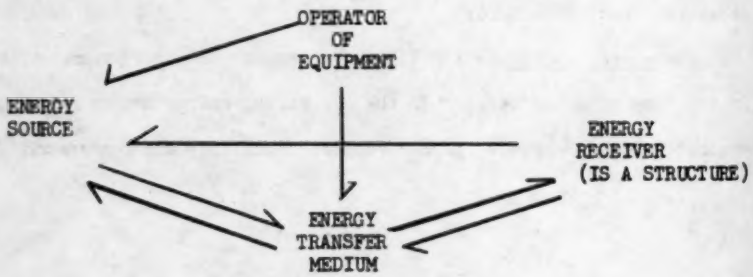
Study and research on aircraft and missile noises require teams of specialists and a general integrative concept which promotes team understanding of the problems and effective approaches to the possible solutions. To attain this goal the Air Force uses the "Acoustic Energy System" concept. Under this concept, we visualize the system in question as containing three major elements. These are: (1) acoustic energy source or sources, (2) acoustic energy transfer media (propagation paths) and, (3) acoustic energy receivers (men, structures).

The energy source is a facility, a machine or a person releasing energy in the form of sound waves. In the Air Force, energy sources are turbojet engines, rocket engines, ground support facilities and equipment. The

energy transfer medium is the material substance (air, earth, structure, etc) through which the acoustic energy is carried away from the source. The energy receiver is the object (structure, machine, equipment, person) which receives or absorbs the acoustic energy carried from the source by the transfer paths. The energy level at any point in the system and its flow are determined by the properties of the system elements and by the interactions among them. The principal energy flow is as follows: ENERGY SOURCE ⟶ ENERGY TRANSFER MEDIUM ⟶ ENERGY RECEIVER. Usually there is some energy loss in the transfer medium, and our most effective means of sound control are obtained by altering the transfer medium to increase its capacity to dissipate acoustic energy. The energy level at the source, its flow, and its level at other points in the system are influenced by interactions among the elements of the system. The principal interactions within the system may be diagrammed as follows:



If the acoustic energy receiver is a structure, as for example, an aircraft wing, a fuselage section, or the surface of a missile, the interactions are more complex, as shown by the following diagram:



When the acoustic energy receiver is a group of "community residents" the interaction channels are much more complex than for the examples given above. This system concept and its applications are also discussed in the article, "Noise, Vibration and People," referenced above.

During the last half of 1952 the Air Force analyzed its research and development effort on aircraft and missile noise in terms of the acoustic energy system concept. Its research program was found to be well balanced with respect to the study of acoustic energy sources, acoustic energy transfer media and acoustic energy receivers. The estimated cost of the Air Force program in 1952 was approximately 1.25 million dollars. Since this was the first detailed Air Force analysis of its efforts to control aircraft and missile noise and because the findings became the basis of an augmented program initiated in 1953 it is reported in some detail in Annex I to this statement (copies available for the record). Annex I, title: "Status of USAF Research and Development on Noise and Vibration Control, December 1952," contains a short history of the problem, a description of programs in being, an outline of future USAF plans and a brief description of the scientific areas included in the USAF plans.

In the first half of 1953 the USAF initiated a single integrated research program on aircraft and missile noise and made a single coordinator and director responsible for it. The general objectives of this program were to achieve, through research in the relevant physical and biological sciences the development of a system: (1) to adequately control human exposure to acoustic energy (vibratory energy), (2) to assure levels of acoustic energy acceptable to humans in their normal environments, (3) to

prevent damage to structures by controlling the acoustic energy to which they are exposed, and to develop general criteria relevant to aircraft and missile noise for airbase planning. The requirements (1953) for this program and a description of specific technical tasks are outlined in Annex II to this statement (copies available for the record).

The USAF requirements (Annex II) were analyzed using the acoustic energy system concept and the needed program was formulated, documented and activated during 1953 and 1954. Annex III, title, "Required Research Program," outlines in detail the scientific areas to be investigated. Copies of Annex III are available for the record. This research and development program on aircraft and missile noise, its generation, its propagation, its effects and its control expanded each year from FY 1953 through FY 1957. Maximum effort was placed on the program in FY 1957. Since the reorientation of the Air Force research and development programs, that occurred in 1958, effort on this program has decreased each year.

This USAF program has been fully coordinated within the Air Force by a special technical coordination office. Coordination with other military services has been achieved by utilizing the services of the Armed Forces - National Research Council, Committee on Hearing and Bio-Acoustics (CHABA). Coordination with NACA, other non-military governmental agencies and industry has been achieved by the technical coordination office and by making use of the NACA Special Sub-Committee on Aircraft Noise with its extensive representation from educational institutions and industry.

In the area pertaining to acoustic energy sources (physical science techniques) the following results have been obtained.

The basic mechanisms by which jet type propulsion systems generate noise have been determined and described. Additional research on these mechanisms may be required in connection with the most advanced rocket engines.

It has been shown that jet and rocket engine sources cannot be designed or modified to achieve major reductions of the acoustic energy generated.

It has been demonstrated (in cooperation with NACA and industry) that airborne suppressors cannot produce major reductions in jet engine noise without introducing reductions in aircraft performance that are not acceptable to the Air Force.

The acoustic energy output (under all important operating conditions) of current Air Force propulsion systems have been determined quantitatively.

Methods have been developed for estimating the acoustic energy output of propulsion systems using data that define their design parameters. These estimates can be made before the prototype systems have been built. Except for the most advanced rocket motors these methods have been experimentally verified.

Principles have been discovered and applied in developing methods for estimating acoustic energy levels on the ground that result from the flight of aircraft overhead.

"Aerodynamic generation of noise," at the surface of aircraft has been studied and the mechanisms of generation determined except for flight at high mach numbers.

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Theories for the generation of shockwaves at supersonic speeds have been developed. They have been experimentally substantiated except for flight at very high mach numbers.

In the area pertaining to acoustic energy transfer media or paths (physical science techniques) the Air Force program has resulted in:

A basic understanding of sound propogation in air (the atmosphere).

Principles for using atmospheric attenuation of acoustic energy as a means of noise control have been developed and applied.

Some understanding of the influence of weather variables has been developed but adequate methods for predicting their influence on noise propagation in some practical situations are not available. Better meteorological prediction techniques are probably necessary before these methods can be improved.

The basic principles upon which to base the design of ground-run-up noise suppressors have been elucidated. Satisfactory engineering application of these principles to ground noise suppressors has not been achieved.

Engine test cell noise control treatments can achieve any desired degree of noise reduction when cost is not a major consideration.

In the Area pertaining to structures as acoustic energy receivers (physical science techniques) we have:

Barely defined the problem for complex structures such as an aircraft wing.

Data upon which to base improved, electronic components resistant to the effects of acoustic energy. However, the responses of complex electronic systems to high acoustic energy levels have not yet been adequately described and quantified.

In the area pertaining to men as acoustic energy receivers (biological science techniques) the Air Force program has produced data and corallery information to support:

Criteria for "long duration" exposures to operational noise environments that assure preservation of normal hearing.

Tentative cirteria for "short duration" exposures to similar noises environments.

Development of personally warn noise protectors that assure preservation of the hearing function of our maintenance personnel.

Tentative evaluation and estimation of the "non-auditory" effects on man of intense noise. However, many new data are required for formulation of adequate criteria.

Preliminary interpretation of the way the mechanical properties of body tissues influence entry of acoustic energy into the human body and its propagation through body tissues. Impulsive application of acoustic energy and its effects are not well understood.

Development of preliminary empirical methods for estimating the response of community residents to aircraft and missile noise. Further validation of these methods is required and they need to be supported by relevant data obtained by new psychological, psycho-physical, psycho-sociological, socialogical, economic and like research.

General and special methods for estimating the effects of aircraft and missile noise on voice communication.

The cost of the Air Force basic and applied research program was approximately as follows:

FY 53	$1.25 million
FY 54	$1.25 million
FY 55	$1.80 million
FY 56	$2.0 million
FY 57	$2.0 million
FY 58	$1.0 million
FY 59	$1.0 million

In addition, engineering developments were carried on at costs estimated to be about one-half of the research costs. Current estimates of the cost of the research program for FY 61 and FY 62 are about $1.0 million each year.

The scientific, technical and support personnel engaged in the Air Force research program on aircraft and missile acoustic energy (noise, vibration) and its control are estimated as follows: In 1952 - 24 to 30; during 1956 and 1957 - 50 to 58; now, 1960 - 30 to 35.

Now (in 1960) there are research requirements still to be satisfied. Some of the important requirements are:

Detailed information about the sound fields of advanced propulsion system sources is needed, including details of the "near field" and detailed phase correlation of the sound field over large areas - for application to the sonic fatigue problem.

Exploration of new mechanisms of acoustic energy generation associated with nuclear propulsion systems and perhaps other new systems.

Measurement and evaluation of the effects of low-frequency re-entry and blast-off sound fields and vibration.

Engineering developments to incorporate available research data in the design of effective ground-run-up suppressors.

Study of the long distance propagation of low frequency sound in relation to missile operations.

Evaluation of the effects on man of very low frequency sound (and vibration) and the impulsive application of acoustic energy of any form.

Determination of the effects of man of very long lasting exposure to sound - operators of satellite and space vehicles.

Evaluation of the significance of the physiological and behavorial changes in man induced by exposure to low level noise - over a very long time period.

Evaluation of the significant psycho physical, psychological, sociological, economic, and other factors that are the basis of adverse community response to aircraft and missile noise.

AIRCRAFT AND MISSILE NOISE--PARRACK ANNEX I

STATUS OF USAF RESEARCH AND DEVELOPMENT
ON NOISE AND VIBRATION CONTROL

12 December 1952

OBJECTIVE

To evaluate the current effort of the United States Air Force with respect to control of noise and vibration produced in all Air Force operations. To portray this effort in the light of past history and supplementary effort by other agencies and organizations. To recommend specific action for the development of a maximally effective future USAF program.

DISCUSSION

History of the Problem

Early Days:

Since the development of the first model, aircraft have been effective noise generators. In early aircraft and also in all that followed, until the development of jet propulsion, the propeller and engine exhaust were the major source of noise. The early engines were imperfect machines, vibrations resulted and were transmitted to the airframe to create secondary noise sources. In the early stages of development the powers involved were small and neither vibration nor noise were given much consideration by engineers.

As the power delivered by the engine increased, vibration damaged the airframe and engineering effort was applied to reduce engine vibration and to prevent its transmission to the airframe. Vibration was held below the structural damage level. However, noise did not damage the airframe, therefore, as more and more powerful engines were developed and used the noise levels attending operation and flight of aircraft increased.

In the early days no one paid serious attention to the effect of aircraft noise on man. As larger open cockpit aircraft were developed, however, pilots reported temporary deafness following flight. Medical personnel interested in problems of flight investigated these effects on hearing but took no action other than to recommend the use of cotton plugs for ear protection. Then the cockpit was enclosed. The pilot was afforded adequate noise protection. The problem did not become serious again until aircraft were propelled by more powerful engines and frequently by more than one engine. Throughout the period from the development of the first airplane to the beginning of World War II airplanes were regarded as novelties by many people. Engine power levels were relatively low, operations (flights) were, in most areas, infrequent and only rarely was the general population sufficiently disturbed by noise to complain.

AIRCRAFT AND MISSILE NOISE--PARRACK ANNEX I

World War II Period:

World War II was the incentive for rapid and spectacular development of aircraft. The size and speed of aircraft increased rapidly. The available power and the number of engines per aircraft increased. The vibration and noise increased. Noise inside the aircraft became a major problem with respect to the use of the radio and the intercommunication system. Large sums of money were spent: (a) in developing communications systems for use in noise; (b) in measuring noise levels in aircraft; (c) in developing materials, types of sound absorbing structures and methods of installing these structures to reduce noise inside the aircraft; (d) in designing, developing and producing ear protectors for use both inside and outside the aircraft and in the industrial plants producing aircraft; (e) in developing special noise excluding devices for preventing entry of noise under the headphones used by aircrews; (f) in developing special noise cancelling microphones.

Examination of the preceding list of activities concerned with noise control reveals that nearly all were directly connected with the preservation of communications capacity. Exact costs of these efforts are not available to the writer but certainly they were several millions of dollars, perhaps between 50 and 100 millions. Nearly all of the work was performed in industrial laboratories and in those of education institutions working under the direction of the National Defense Research Committee.

It is noteworthy that, except for the effort devoted to developing ear protectors for industrial workers, almost this entire effort was made on behalf of aircrew members and to assure adequate communications. Ear protectors could be used by aircraft ground crews, but were not specifically designed for their use. Essentially no effort was devoted to providing protection for personnel located at some distances from the aircraft or the noisy air operation. No consideration at all was given to those incidentally residing or working in the vicinity of such operations. However, community complaints were not serious, it was wartime, a time of hardship, noise was tolerated.

Post World War II Programs:

The close of World War II reduced to a certain extent the pressure for immediate, interim, practical solutions to certain of the noise problems. Time was available for consolidation of the gains accruing from the war time effort. It was possible to evaluate existing information and plan (at least tentatively) long range programs to provide more adequate solutions to the many noise problems arising from aircraft production, operation and maintenance.

However, technical developments that come to fruition just before and immediately following the close of World War II were to reduce, in some measure, the time available for working out adequate solutions to the noise problems. Jet and rocket type power plants were developed and their application to aircraft propulsion increased rapidly. These power plants created special problems. More powerful conventional engines and propellers, developed during the war, were utilized on commercial passenger and cargo aircraft. Commercial

airline operations and also U. S. Air Force operations increased. All these factors, perhaps many others, were to alter completely the entire problem of aircraft noise and vibration control and to project us rapidly into the present problem era.

Immediately following World War II, however, the Aircraft Laboratory, Wright Air Development Center (ARDC) consolidated the data on "Noise Control for the Interior of Aircraft" and specified the noise control installation to be used in different types of aircraft. The same laboratory instituted long range programs for the improvement of noise control techniques and materials. At about the same time the Communication and Navigation Laboratory (Wright Air Development Center, ARDC) undertook the development of an improved aircraft communications system. This work was assigned to Radio Corporation of America under Contract No. W33-038-ac-18181 for the development of high intelligibility interphone systems for military aircraft, as specified in Exhibit TSELT-171, dated 7 March 1947. High noise levels in aircraft were recognized as an important problem and effort was to be devoted to designing special features for controlling the adverse effects of noise on communication. These efforts included the design of noise cancelling microphones, noise excluding earphone cups, etc. Somewhat earlier than this (1946) an entirely new Air Force Program was initiated at the Aero Medical Laboratory. This program was devoted to the determination of the effects of noise and vibration on man, and to the development of means for protecting him from noise and vibration. The program contemplated the "Man - Noise and Vibration Complex" as a unit area for investigation. This area included: (a) studies on properties and responses of the human body and all its receptor mechanisms; (b) the development of protection by any available means including changes in the design of the machine, the application of noise and vibration absorbing structures, the development and application of personal protective equipment, etc.

This entire program was initiated by the activation of Research and Development Order (RDO) No. 695-63, entitled, "Hazards to Flying Personnel from Mechanical, Sonic and Ultrasonic Vibrations" submitted 4 April 1946 and approved 26 July 1946. The initial program was supplemented by the program required by Technical Instruction No. 2110, Addendum 11, dated 18 July 1946, subject: "Effects of Pulse Jet Engines on Personnel." These actions marked the beginning of a comprehensive program which considered man and all aspects of his functional capacity in relation to noise and vibration produced in any or all operations of the Air Force. This program emphasized personnel protection, since T. I. 2110, Add. 11, specifically directed: "If harmful effects are definitely proven, protective measures for both flight and ground personnel should also be investigated."

Because of the publicity given to "rumored effects" of sound waves of ultrasonic frequency, the first three (3) years of this program placed maximum emphasis on "the determination of the effects of airborne ultrasound on man". To accomplish these studies a contract was made with Ultrasonic Corporation, Cambridge, Massachusetts for the development of a siren described as "Sound Source Assembly, Covering the Frequency Range 10 cps to 200 Kcps and Accessory

Control Measuring Instruments". The siren developed under this project (Contract No. W33-038-ac-16045 and Supplemental Agreement No. 3 thereto) was completed and installed 22 August 1949 at a total cost of $107,089.00.

Utilizing this equipment studies were completed at the Aero Medical Laboratory which established the fact that "there is no hazard to personnel from airborne sound of ultrasonic frequencies (20,000 cps and above) generated by present USAF power plants or equipment. Furthermore, there is no probable hazard to personnel from these sound waves generated by equipment that will be available in the foreseeable future."

Present Programs:

Beginning phases: (WCRDB, WADC)

The present program is considered as beginning in December 1948 because several important contracts, which are part of the current program started at that time. The first of these is Contract No. AF 33(038)-500, with Washington University, St. Louis, Missouri, dated 3 December 1948, entitled "Study of the Histological Changes of the Inner Ear Induced by Intense Sounds," cost, $7,626.00. The work in this area by Washington University has been continued to the present date by Supplemental Agreements: No. 1, dated 1 January 1950, cost, $5,538.08; No. 3, dated 30 December 1950, cost $5,000.00. The second important early contract, still active, was made with the Pennsylvania State Collect, State College, Pennsylvania on 13 December 1948 (Contract No. AF 33(038)-786, cost, $47,470.00). The work to be performed was described as "Studies on the Builogical Effects of High Intensity Sound Waves." This work was to be accomplished by a team of scientists drawn from four departments of the College; (a) Department of Physics, (b) Department of Psychology, (c) Department of Bacteriology and (d) Department of Zoology. Effort on this project has been continued by Supplemental Agreements; No. 2, dated 3 March 1950, cost $47,470.00; No. 3, dated 6 March 1951, cost $48,000.00. This work has resulted in a much clearer understanding of the effects of intense sound on man and animals, in such areas as psychological reactions, heating by intense sound, and tissue pathology produced by intense sound. The detailed scientific findings have been reported in fourteen Technical Reports and published papers. A third important contract is that with Central Institute for the Deaf, Contract No. AF 33(038)-18682, made on 11 January 1951 at a cost of $10,000.00. This project called for the "Acoustic Evaluation of Certain Items of Personal Equipment". Under this contract the effectiveness of several different types of ear plugs was determined and their relative merits stated. In addition, the "noise excluding" characteristics of the new oxygen helmet were measured and compared with similar characteristics of earlier equipment. The fourth contract, opened in the beginning phase, was that with the University of Illinois (Contract No. AF 33(038)-20922, dated 2 March 1951, cost $16,000.00), for study on "Physics of the Action of Intense High Frequency Sound on Vertebrate Tissues." This project has resulted in four (4) or five (5) scientific papers on the effects of high frequency sound on nervous tissue and on the physical properties of tissues.

AIRCRAFT AND MISSILE NOISE--PARRACK ANNEX I

During this period the USAF School of Aviation Medicine, Randolph Field, Texas, carried on investigations under Project No. 21-27-001, or its predecessors, which were concerned with auditory acuity of Air Force Personnel, Standards of Hearing, Hazards to Hearing and Protection of the Hearing Organ.

Outside the United States Air Force limited programs were carried on by the organizations listed below:

(a) NACA - Mufflers for control of noise from jet engine test cells and some work on quieting of the 8 x 6 foot wind tunnel located at Lewis Flight Propulsion Laboratory.

(b) General Electric Company - Started practical installation of jet engine test cell mufflers of their own design and carried out a few studies to evaluate their effectiveness.

(c) General Motors Corporation, Allison Division - Designed, installed and operated jet engine test cell mufflers. Some effort was made to obtain evaluation of their effectiveness and to determine the service life of the different designs.

(d) North American Aviation, Inc. - Began studies about 1950 on scale models of engines and test cells to determine certain parameters for test cell muffler design. Also built and evaluated a portable turbojet engine test cell noise suppressor and an aircraft run-up noise suppressor.

Current Phases: (WCRDB, WADC)

At the present time there is one active planned program in the United States Air Force devoted completely to various aspects of noise and vibration control. This program is carried on by the Bio-Acoustics Section, Aero Medical Laboratory, Directorate of Research, Wright Air Development Center (ARDC). The important scientific areas under investigation in this program are outlined in the section entitled "Scientific Areas." A summary of the known current effort on problems of noise and vibration control follows:

Current Effort, United States Air Force:

The Wright Air Development Center program is currently carried on under two (2) Research and Development Orders. These are; (a) RDO 695-63, entitled: "Action of Vibration, Sonic and Mechanical on Air Force Personnel." Date of last major revision, 15 April 1951, (b) RDO 695-74, entitled: "Noise Defenders for the Ear", approved April 1951. The scope of RDO 695-63 is broad and includes the entire area of Air Force noise and vibration control (see Appendix I). RDO 695-74 is restricted to problems of protecting the hearing organ from Air Force noise and vibration. A summary of the activities carried on under these two (2) Research and Development Orders follows.

AIRCRAFT AND MISSILE NOISE--PARRACK ANNEX I

Washington University, Medical School: Under Contract No. AF 18(600)-58 this institution is performing work on a project entitled, "Pathology of Mannalian Ears Produced by Intense Sound." The work to be performed consists of: (a) the restudy and description of the detailed pathology of the ears exposed, in earlier studies, to very intense sound (siren); (b) the determination of the influence of past exposure life on the pathology induced in mammalian ears by intense sound; (c) the correlation of physiological response decrement with the pathology produced in mammalian ears by exposure to intense sound. Physiological methods are here combined with those of pathology so, that one may finally predict the pathology from physiological studies or vice versa. Two (2) technical reports have been submitted and three (3) or four (4) papers for publication are now in preparation. This project has provided a better understanding of pathology produced by intesne sound.

The Pennsylvania State College: Under Contract No. AF 33(038)-786, The Pennsylvania State College is engaged in general Bio-Acoustic studies on the Action of Intense Sound. A major task now in the planning stages is the "determination of the human threshold for hearing as altered by age, in a populated exposed to very light industrial noise. Other phases of the program continue the studies on the direct action of intense sound on living tissues. Certain other studies are directed toward determining the physical properties of living tissue.

The Central Institute for the Deaf: Under Contract No. AF 18(600)-131, The Central Institute for the Deaf is engaged in a study of the "Effects of Intense Low Frequency Sound on the Human Ear." This study is primarily aimed toward determining the validity of the currently used, "Tentative, Deafness Risk Criterion," and the determination of the masking effects of low frequency sounds (100 cps and below) on speech. These data are expected to provide a basis for establishing new "Speech Interference Criteria" if the currently used Tentative Criteria are found unsatisfactory. Another phase of this program will attempt to find a correlation between the temporary auditory fatigue of very short exposure to sound and susceptibility to permanent deafness. All of these areas are of major practical importance for the formulation of final "Criteria for Human Tolerance to Noise."

The University of Illinois: The University of Illinois program, under Contract No. AF 33(038)-20922 is directed toward the determination of the effects of high frequency sound (above 50,000 cps) and the determination of the physical constants of living tissues. The central nervous system has been found to be expecially susceptible to high frequency sound and this project will explore this area thoroughly.

Bolt Beranek and Newman: Under Contract No. AF 33(038)-20572 the acoustical consulting firm of Bolt, Beranek and Newman are preparing a "Handbook of Acoustic Noise Control." The first volume is devoted to physical aspects of the problem and the second volume considers the human response. This handbook provides a unified approach to the problem of noise control, gives technical information on methods that may be employed, evaluates current methods and devices and provides tentative working criteria for man's response to noise.

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Massachusetts Institute of Technology: An experimental and theoretical investigation of noise generation by gas jets and the influence of gas temperature on noise generation has been undertaken by Massachusetts Institute of Technology. The program is carried on under Contract No. AF 33(616)-149.

Brown University: A program to consolidate and evaluate existing information on all aspects of sound propagation through air, near the earth's surface, has been undertaken by Brown University. The project is to provide practical guides for utilization of atmospheric variables for noise control or determine whether such guides are feasible. The probability or obtaining useful practical guides through further research will be determined. The work is supported by Contract No. AF 33(616)-340.

Mine Safety Appliances Company: Under Contract No. AF 33(600)-20451, the Mine Safety Appliance Company is developing experimental "over-the-ear noise protectors". The purpose is to determine whether effective protectors of this type can be built. If successful, specifications for the over-the-ear protector will be prepared.

Louis McLean: A program to evaluate the effectiveness of individually fitted ear plugs is supported by a contract with Louis McLean, who furnishes the individually molded plugs. The program will determine whether this type of plug is preferrable to standard plugs which are mass produced.

Commonwealth Engineering Company of Ohio: A program for the development of a 21-channel noise analyzer has been undertaken by Commonwealth Engineering Company of Ohio. The work is being performed under Contract No. AF 33 (600)-18681. The multichannel analyzer will materially speed up the analysis of noise and is also applicable to speech analysis and many other analysis problems.

Intra-mural Effort (WCRD):

In addition to the contractor effort, the Bio-Acoustics Section has twelve (12) full-time scientists engaged on various aspects of the overall problem. Major effort is devoted to hearing and its preservations, analysis of typical Air Force noise structures, evaluation of noise control devices and development of personal noise protective devices. These personnel are supported by special equipment, valued at approximately $500,000.00. Inadequate workspace is the major limitation on the productivity of the group.

Effort by Other WADC Organizations:

In the Directorate of Laboratories the following laboratories maintain supporting programs. The Aircraft Laboratory has programs for measurement of aircraft noise, development of improved noise control materials and methods for use in aircraft and investigation of aerodynamic generation of noise. The cost of these programs is estimated at $75,000.00 per year. The Power Plant Laboratory has a program for development of noise control in engine test cells. A noise survey of Wright-Patterson Air Force Base is planned in cooperation

with the Bio-Acoustics Section. The General Electric Company has provided designs for noise control installations for test cells. The current cost of this program is estimated at $100,000.00 per year. The Equipment Laboratory has a program for noise control in aircraft ventilating systems. This project is estimated to cost $20,000.00 per year.

Effort by Other USAF Activities:

The USAF School of Aviation Medicine has a program primarily devoted to clinical aspects of the effect of noise on hearing. The cost of this program is estimated at $50,000.00 per year.

The Air Material Command, Air Installations Section, Air Installations Section, has designed several noise control installations for engine test facilities within the Command. These are practical installations but evaluation of their effectiveness is of major value to research and development programs, since the data is from full scale noise control devices. The value to research and development effort of these installations is estimated at $200,000.00.

The Air Materiel Command, Industrial Facilities Branch provides similar facilities to contractors and each facility provides a new type of noise control design. The cost of these facilities runs into millions of dollars. The research and development data available can replace at least $250,000.00 worth of experimental full scale designs.

The Air Material Command, Office of the Air Surgeon, obtains field data on noise and on human response which is very useful in guiding the research development program. Estimated value of this information is $25,000.00 annually.

Other Air Force agencies such as The Strategic Air Command obtains data, from time to time, which is of value to research and development on Air Force noise and vibration control. It is not possible to place a dollar value on these sources of data.

Non-USAF Agencies:

The Department of the Navy has small programs in force at Philadelphia (Naval Aero Medical Equipment Laboratory) and at Naval Medical Research Institute. The first is concerned with responses of man to noise and the second is chiefly devoted to effects of mechanical vibration. Recently the Bureau of Medicine (USN) has become greatly concerned about operation of afterburners from carriers. As a result of the aircraft carrier situation, the Navy Department, (BU MED) requested the assistance of the National Research Council (NRC). The NRC requested a survey of the area including Department of Defense and civilian organizations. This survey was carried out by Professor Walter A. Rosenblith, Massachusetts Institute of Technology and Dr. Douglas E. Wheeler, Field Representative, Sub-committee on Noise in Industry, American Academy of Ophthalmology and Otolaryngology. The

recommendations of this team were reported to the NRC on 3 November 1952. Among the important recommendations were; (1) The provision of more adequate facilities by the Department of Defense, (2) A coordinated program in each service, directed by one person, competent in the area, (3) An effective coordination of the programs of the three (3) services, (4) An advisory group consisting of specialists in all subjects involved to assist the three (3) service directors. As a result of this survey and because of the crucial problems involved in carrier operations it is anticipated that the USN effort will be greatly increased. The dollar value of the program of the U. S. Navy is not available.

NACA: The National Advisory Committee for Aeronautics has been active during the past year on the problems reducing the noise from aircraft in flight. Some fundamental studies are in progress on the generation of noise by various propulsive devices and on evaluating the means for designing equipment to produce less noise. The cost of these programs is not known.

CAA: The Civil Aeronautics Administration has a committee on noise problems of aircraft operations. The extent of their effort is now known, nor is the cost.

AIA: The Aircraft Industries Association has a committee on noise reduction. It has formulated standard measurement techniques for use of its members. Otherwise, in so far as is known, the effort on the problem is that of the individual member companies.

Aircraft and Aircraft Engine Manufacturers: Nearly all airframe manufacturers and many engine manufacturers have noise control programs. In many instances the actual effort is financed by the USAF or the USN. The cost of the effort is now known. Several installations for noise control, built by these organizations, should be completely evaluated, and their effectiveness determined. Thereby, costly ineffective designs could be avoided in the future.

FUTURE PLANS

The United States Air Force: Future plans for the USAF Research and Development Program on Air Force Noise and Vibration Control contemplate: (1) Sustained effort on the general program at least equal to the current level; (2) Increased effort in certain critical areas, as for example, (a) control of noise for community protection, (b) evaluation of the potentialities for noise reduction at the source; (3) Further development of the present comprehensive, coordinated approach (Directive letter from Headquarters Air Research and Development Command to Wright Air Development Center, dated 28 November 1952, subj, 'Air Force Noise and Vibration Control'); (4) Construction of the Wright Air Development Center, Bio-Acoustic Research Facility as proposed in the approved FY-54 facilities program, to accelerate research and development production in this area; (5) Utilization of the technical assistance of the recently formed Armed Services - National Research Council Committee on Hearing and Bio-Acoustics in the entire area comprised by the

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"Man - Vibratory Energy" complex; (6) Complete implementation of the recommendation, "that the military research program in noise reduction be drastically increased on two major problems; (a) ----; (b) "Reduction of noise of high performance aircraft", contained in the Program Guidance prepared by the Sub-Panel on Acoustic Noise Reduction, Panel on Acoustics, Electronics Committee, RDB (Ref. RDB, LEA 107/2 and LEA-NR 3/4, dated 23 October 1952).

United States Navy: Exact plans of the United States Navy for the future are now known, but the crucial problems created by afterburner equipped turbo-jet engines dictate increased effort in the area of aircraft noise and vibration reduction. Participation in the program of an cooperation with the Armed Services - National Research Committee on Hearing and Bio-Acoustics is assured.

NACA: The National Advisory Committee on Aeronautics can be expected to maintain its present level of effort and perhaps increase this effort in the area of community protection from aircraft noise.

Other Organizations: It is anticipated that all other organizations now working in this problem area will continue work at not less than the present effort level. Such organizations are; CAA, AIA, all airframe manufacturers, all engine manufacturers, and all operating commercial airlines.

CONCLUSIONS

1. The current United States Air Force considers all significant aspects of the total problem area designated "Man-Vibratory Energy Complex."

(a) Critically important subdivisions of this area are:

(1) Protection of residents of communities located adjacent to "take-off" and "landing" flight paths.
(2) Protection of ground personnel, particularly line maintenance personnel.
(3) Evaluation of the potential for noise reduction at the source in aircraft power plants.
(4) Preparation of validated criteria for human tolerance to noise and vibration which are correlated with the functions personnel are to carry out under exposure.

2. The current direct USAF Research and Development effort on this problem area costs in excess of $614,000.00 annually. Indirect support of this USAF effort is valued at more than $475,000.00. The cost of the total USAF effort is in excess of $1,000,000.00 annually.

3. Best estimates of the effort of other interested organizations indicate none of them are making a greater effort.

4. An increasingly effective program can be achieved by increased coordination of effort and development of improved methods for desseminating correlated and integrated information.

5. The USAF should sustain the present effort level on the general research and development program. Certain specific areas require increased effort; (a) problems of community protection; (b) evaluation of the potentialities for noise reduction at the source; (c) protection of USAF personnel.

6. The future USAF research and development program can be made maximally effective through; (a) increasingly unified direction; (b) more complete coordination with other services and civilian agencies; (c) the construction of the proposed Wright Air Development Center, Bio-Acoustic Research Building; (d) complete utilization of the technical capabilities of the Armed Services - National Research Council Committee on Hearing and Bio-Acoustics.

RECOMMENDATIONS

1. That the United States Air Force Research and Development Program on Noise and Vibration Control be implemented at a maximally effective level by the following action:

(a) Retention and further expansion of the present unified, comprehensive approach.

(b) Continued effort to achieve complete coordination of effort.

(c) Construction of the WADC, Bio-Acoustic Research Facility.

(d) Maximal utilization of the technical capabilities of the Armed Services - National Research Council Committee on Hearing and Bio-Acoustics.

(e) Placing increased effort on the critically important subdivisions of the total area, as listed in conclusion one (1).

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SCIENTIFIC AREAS

General Area of Interest:

The Bio-Acoustics Section is concerned with the solution of problems pertaining to the interaction between man and vibratory energy. Vibratory energy is understood to mean sound and mechanical vibrations of all frequencies and all energy levels. Practical limits to the area of effort are established by the frequency ranges and energy level ranges of sound and vibration found in or about aircraft or attending any support operation or activity carried on by the United States Air Force. Evaluation of the entire problem area comprising the "Human Reaction - Vibratory Energy" complex reveals the following general and specific problem areas of major importance.

Physical Studies on the Human Body:

The determination of the mechanical properties of the human body surface that control the entry into it of vibratory energy.

The determination of those physical properties of tissues that control the propagation, distribution, and dissipation of vibratory energy inside the human body.

The determination of the mechanical and physical properties of the ear and all other sensory end organs acted upon by vibratory energy.

The study of the mechanical properties of those body structures that control the generation of, and influence the quality of, the human speech signal.

The determination of the influence of the mechanical properties of body tissues on transmission through the tissues, and surface radiation of internally generated vibrations or vibratory forces applied to localized areas of the body surface (essential for recording and measuring body responses to vibration).

Physiological Studies on the Human Body:

The determination of the normal response characteristics of the sensory mechanisms responding to vibratory energy (the ear; vestibular mechanism; joint, muscle and tendon receptors; etc.).

The determination of the levels of vibratory energy as a function of frequency that induce abnormal functioning of receptor mechanisms (masking in the ear, in coordinated movements, etc.).

The determination of the levels of vibratory energy that produce pathological alterations in receptor mechanisms or functional systems (temporary deafness, permanent deafness, circulatory disturbances in extremities and joints, paralysis, etc.).

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Physical Description of Vibratory Energy Fields:

Measurement of intensity versus frequency and intensity versus time of sound fields generated by power plants and any other equipment used in the Air Force.

Measurement of the frequency and amplitude of mechanical vibration present in aircraft and any other equipment used in the Air Force.

Experimental and Theoretical Studies on Sources of Vibratory Energy:

Detailed study of noise generated by power plants and other sources in combination with other physical measurements that will give information about the mechanisms responsible for the noise generated (turbo-jets, rockets, high velocity air jets).

Development of mathematical theories pertaining to the generation and radiation of sound by Air Force sources to serve as guides to the design of experimental procedures and to the better understanding of the mechanisms of sound production.

Detailed studies of the properties of the common sources of mechanical vibration that are found in USAF equipment.

Experimental and Theoretical Studies (physical) of the Influence of the Medium in which Sound is Propagated:

The determination of the mechanisms which control the dissipation of the energy of sound waves as they travel through air near the earth's surface.

Determination of the influence of meteorological states of the air near the earth's surface on attenuation and scattering of sound waves traveling in this medium.

Studies of the influence of the air on propagation of finite amplitude sound waves.

The elaboration of extended mathematical theories in these areas to better explain the effect of the medium on propagation of waves of extremely great amplitudes.

Evaluation of Acoustical Principles Applicable to Sound Control:

Investigation of the physical properties of materials that may be used for fabrication of personal protective equipment.

The determination of the major acoustical principles that may be employed to achieve design of effective personal protective equipment.

Determination of mechanical and physical properties of structures and devices used for the reduction of sound between the source and the human occupants of the environment.

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Development of improved materials for sound control.

Elaboration of the important acoustical principles that may be employed in the design of structures and devices for sound control (mufflers, buildings, etc.).

Special Methods and Equipment:

Development of methods and special instrumentation for the measurement, recording and analysis of very intense sound waves (pressure variations greater than 0.5 atmosphere) in the sub-audible and audible frequency ranges.

Development of improved, precise and rapid techniques, methods and instrumentation for the analysis of the complex, intense sound waves, classified as aircraft noise.

Development of novel, effective and rapid means of recording, measuring and analyzing responses of man to intense sound waves.

Development, where needed, of techniques for effective presentation and interpretation of data obtained from studies in the area described as the "Man - Vibratory Energy" complex.

Assessment of existing methods and development of new methods for detecting and recording internal responses of man to vibratory energy (chemical responses, internal organ functional responses, etc.).

Development of techniques and equipment of specific interest to Industrial Medical and Industrial Hygiene Engineers.

Formulation of Criteria:

Criteria for maximum allowable levels of vibratory energy consistent with prevention of pathological changes in the body (permanent hearing loss, circulatory pathology, etc.).

Criteria for maximum allowable levels of vibratory energy consistent with the maintenance of normal physiological functions (speech communication, sleep and rest, vision, etc.).

Criteria for design of effective personal protective equipment.

Criteria for design of effective noise control structures and devices.

Criteria for the maximum allowable levels of vibratory energy falling upon residents of communities which surround air bases or are under flight paths of operational aircraft.

Preparation and Dissemination of Unitized Statements of Methods, Techniques, Interpretations and Criteria Derived from Experimental Data:

Correlation, integration and evaluation of experimental data essential to the preparation of a unitized statement pertaining to a specific topic, for example, "Air base planning."

Collection, compilation and analysis of experimental data from all available sources.

Preparation in practical form, as determined by the intended use, of unitized statements on specific topics.

Development of procedures for adequate dissemination of unitized information and dissemination of this material.

SUMMARY

Review of the current USAF Research and Development Program reveals: (1952)

The annual value of the USAF effort is:

Current contractor direct Research and Development effort is valued in excess of $614,000.00.

Indirect contractor support of Research and Development is valued in excess of $475,000.00

Total contractor effort of the USAF is valued in excess of $1,100,000.00.

Total AF personnel time is valued in excess of $141,000.00.

Total USAF effort is valued in excess of $1,241,000.00.

Best estimates indicate that no other Department of Defense, Governmental or civilian agency is making a greater effort in this area.

The current USAF program attacks all aspects of the problem.

There are critically important areas of the overall problem that should be prosecuted at an increased rate:

Protection of community residents living near air bases.

Protection of AF ground personnel (maintenance, etc.).

Preparation of validated criteria for human tolerance to noise and vibration.

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Evaluation of the potentialities for noise reduction at the source.

The Future USAF Research and Development Effort can be made Maximally Effective by:

Retention and further expansion of the present unified, comprehensive approach.

Continued effort to achieve complete coordination of effort.

Construction of the WADC, Bio-Acoustic Research Facility.

Maximal utilization of the technical capabilities of the Armed Services - National Research Council Committee on Hearing and Bio-Acoustics.

Placing increased effort on critically important areas of the total problem.

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REQUIREMENTS

General Requirements:

The intense vibratory energy fields (noise and vibration) produced by operating Air Force equipment and facilities (particularly jet and rocket power plants, supersonic propellers, jet and rocket propelled aircraft, flight line maintenance operations, power plant maintenance and test facilities) have created problems, with respect to the control of vibratory energy, the magnitude and seriousness of which generate specific USAF requirements.

Specific Requirements:

Human Exposure to Vibratory Energy:

There is a requirement to develop a system to control human exposure to hazardous vibratory energy levels (noise and vibration). Development of the control system requires development of:

Criteria for human tolerance to vibratory energy with respect to the production of:

pathology

hazardous physiological reactions

hazardous psychological states

hazardous behavioral responses

Techniques, procedures and equipment to prevent human exposure to vibratory energy.

Equipment, buildings and operational procedures to reduce vibratory energy below hazardous energy.

Human Acceptance of Vibratory Energy:

There is a requirement to reduce vibratory energy (noise and vibration) to levels acceptable to personnel employed or residing in proximity to USAF sources. This requirement entails:

Development of criteria for human acceptability with respect to:

personnel engaged in various assigned duties.

personnel who reside near vibratory energy sources.

vibratory energy levels which permit effective accomplishment of necessary functions during exposure.

the levels of vibratory energy produced by flight operations which are tolerable to residents of communities, located adjacent to USAF Air Bases.

vibratory energy levels which insure no damage to community residents or their possessions both animal and real estate.

Development of Noise Reduction Means, as required by the criteria for human acceptability by:

utilizing the attenuating properties of the atmosphere.

effective use of intervening structures.

development and application of vibratory energy attenuating equipment and structures.

development of design techniques for "Source-Noise" reduction.

Human Exposure to Hot Gas Blast:

There is a requirement to develop equipment and techniques to control human exposure to blast from hot gas jets produced by power plants. The control measures developed shall:

Reduce the vibratory energy of blasts to levels within human tolerance limits.

Reduce accompanying noise to levels within the human tolerance limits established by the criteria for human acceptability.

Afford protection for structural elements near the jet blasts.

Provide heat reduction, as required by personnel working near the gas jets.

Exposure of Structures to Vibratory Energy.

There is an additional requirement to develop means to control vibratory energy, produced by propulsion devices, so that damage to structures is prevented. Reduction of vibratory energy is required:

To prevent damage to airframes and airfoils.

To prevent damage to buildings, ramp and runway structures adjacent to operating aircraft or power plants.

General Criteria:

There is a requirement to develop general criteria for air base planning which make possible the use of all means for attenuating vibratory energy. These criteria shall include:

Criteria for the protection of civilian populations residing near air fields.

Criteria that will support the determination of the type of aircraft that may be operated from a specific base.

Criteria that will support a determination of the type of operation that may be carried out from a given base.

Criteria, based on factual knowledge of the effects of vibratory energy on normal individuals, that are applicable to individuals on the ground and to his possessions, both animal and real estate.

OUTLINE OF REQUIRED PROGRAM

The Air Research and Development Command cited certain specific areas of activity that would be included in the overall program on development of a system for control of vibratory energy. The cited areas of effort are summarized as follows:

Directed Developments

"You are requested to develop a procedure for determining the hazards incident to exposure to":

Vibratory energy produced by operating aircraft.

Jet and rocket power plants.

The development of a procedure to control the effects of exposure through development of:

protective techniques

protective operational procedures

protective equipment (personal)

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The development of means for control of vibratory energy by:

development of methods for vibratory energy attenuation

development of attenuating equipment

development of techniques for "source-noise" reduction

Development of criteria for use in air base planning.

Specific Tasks

"The following specific tasks will be accomplished".

Determine noise levels in areas near all current jet aircraft.

Develop a technique capable of precise prediction of noise levels at various distances from current aircraft and reasonably exact predictions at various distances from newly developed aircraft, when data are obtained from one set of measurements made near the aircraft.

Design a reliable method for predicting the effect of the local meteorological conditions on the spread of noise into areas surrounding operating aircraft.

Develop procedures and equipment to protect personnel from the deleterious effects of exposure to intense noise and vibration, and to permit accomplishment of necessary functions with reasonable efficiency during the time of exposure.

Develop equipment and techniques for the reduction of noise and vibration levels to acceptable magnitudes consonant with the types of activities normally to be expected at various distances from noise sources.

Develop criteria, based upon factual knowledge of the effects of noise and vibration on normal individuals, necessary to air base planning, with particular reference to noise and nuisance as they relate to the individual on the ground and to his possessions , both animal and real estate.

Engage in basic and applied research into problems of sound attenuation, diminution at the source and protection of exposed personnel.

REQUIRED RESEARCH PROGRAM

Analysis of this problem area shows that the required research pertains to a three (3) element system. The elements of the system are:

(1) Vibratory Energy Sources (that produce energy as noise and mechanical vibration);
(2) Intervening Media (through which the vibratory energy flows);
(3) Man or other Living Systems (upon which the vibratory energy falls and produces either desired or undesired effects).

The problem area can be divided, therefore, into three (3) major sub-areas consisting of problems pertinent to each of the elements of the system, namely:

(1) Vibratory Energy Sources;
(2) Intervening Media;
(3) Man

This general outline of problems pertaining to the system, Vibratory Energy Sources - Medium - Man, applies to each operational system, used by the USAF, in which sound (noise) and mechanical vibration are the forms of vibratory energy of interest.

To evaluate this system and to determine where action is required for man's protection we must possess quantitative information about each of its elements. General criteria are needed in addition to the criteria pertinent to each system element. These general criteria are to be used in solving problems, such as; (a) Air Base Planning, (b) Designing Operational Procedures for Equipment and Facilities and (c) Evaluating Neighborhood Response to USAF Operations.

When sufficient quantitative information about (1) the Vibratory Energy Sources, (2) the Intervening Media and (3) Man and his Responses has been acquired the reduction in vibratory energy level required to assure man's safety, health and effective performance can be determined. When control of vibratory energy is required there are several means of achieving this control. Operational Procedures and 'Source Reduction' of Vibratory Energy are the two measures, outlined under the Protective System, that apply to Energy Sources. Three measures, Attenuating Structures, Distance and Geometrical Arrangement and Protective Structures, apply to the Intervening Medium. One measure, Personal Protective Equipment, applies to the medium immediately adjacent to Man. The remaining three measures, Medical Examination, Exposure Control and Education, apply to Man.

One must continually keep in mind the fact that this analysis of the system, Vibratory Energy Source - Medium - Man applies to any operational system used by the United States Air Force. Likewise, the criteria (quantitative information) and the protective measures pertaining to each element of

this system apply to any operational system, as for example, (a) an airplane in flight; (b) an airplane operated on the ground; (c) an engine test cell in operation; (d) a machine shop operation; (e) the operation of office, warehouse or laboratory equipment. The parameters of the Vibratory Energy Sources may differ, both qualitatively and quantitatively and the properties of the Medium may vary but the essential elements composing the system remain the same. The USAF Research and Development Program on Noise and Vibration Control can be divided, therefore, into three major Sub-Programs. Each Sub-Program will deal with problems pertaining to an element of the system, namely: (1) Vibratory Energy Sources; (2) Intervening Media; (3) Man. An outline for a complete program, arranged under the above headings, is presented below.

Major Sub-Programs of Research:

1. Vibratory Energy Sources (Noise and Vibration Sources):

A few typical USAF vibratory energy sources will be selected to illustrate operational systems of major importance. Many other systems exist and new ones will develop in the future. Some typical USAF operational systems which are vibratory energy sources of major importance are:

1.1. Aircraft - Fighter, Bomber, etc.
1.2. Unconventional take-off systems, etc.
1.3. Missiles, etc.
1.4. Jet-engines (turbo-jet, pulse-jet, ram-jet, rockets, etc.)
1.5. Propellers and reciprocating engines
1.6. Airborne equipment, accessories, etc.
1.7. Aircraft ground support equipment, etc.
1.8. Aircraft engine test facilities, etc.
1.9. Airplane and engine maintenance shops, etc.
1.10. Air base maintenance equipment, etc.

To evaluate the action of the vibratory energy on man, to predict community response, to design energy control procedures and to plan Air Bases the following classes of information are required with respect to each source: (1) Quantitative Description as a Unit Acoustic Source; (2) Description of the Principal Sub-Sources; (3) Operational Characteristics. If we use an aircraft (1.1.) as an example, the principal problem areas are as follows:

1.1. Aircraft - B-47B

1.1.1. Description as Unit Acoustic Source
1.1.1.1. Total Acoustic Power Output
1.1.1.1.1. Directivity of Radiation
1.1.1.1.2. Frequency Distribution of Power
1.1.1.2. Acoustic Radiation - Ground Operation
1.1.1.2.1. Directivity of Radiation
1.1.1.2.2. Influence of Engine Power Setting
1.1.1.2.3. Influence of Engine Mounting

1.1.1.3. Acoustic Radiation - Flight Operation
1.1.1.3.1. Directivity Radiation
1.1.1.3.2. Influence of Engine Power Setting
1.1.1.3.3. Influence of Aircraft Control Surfaces
1.1.1.3.4. Influence of Flight Speed
1.1.1.3.5. Variation with Take-off and Landing
1.1.1.4. Noise Levels in Aircraft
1.1.1.4.1. Relation to Crew Positions
1.1.1.4.2. Variability with Flight Conditions

1.1.2. Principal Acoustic Sub-Sources
1.1.2.1. Engines - and other Propulsive Units
1.1.2.1.1. Jet Stream Source
1.1.2.1.2. Engine Compressor Source
1.1.2.1.3. Combustion as Source
1.1.2.2. Aerodynamic Acoustic Sources
1.1.2.2.1. Influence of Shape, etc.
1.1.2.3. Equipment and Accessory Sources
1.1.2.3.1. Ventilating - Heating System
1.1.2.3.2. Electrical Power Equipment
1.1.3. Operational Characteristics (Aircraft)
1.1.3.1. Ground Operational Characteristics
1.1.3.1.1. Take-off Roll
1.1.3.1.2. Crosswind Characteristics
1.1.3.1.3. Speed at Take-off
1.1.3.2. Flight Operation Characteristics
1.1.3.2.1. Air Speed - After Take-off
1.1.3.2.2. Rate of Climb
1.1.3.2.3. Radius of Turn
1.1.3.2.4. Altitude for Turn
1.1.3.2.5. Required Power - Approach and Landing

The research program as outlined for an aircraft is applicable to each typical USAF Source. The relative importance of each area of knowledge may change with the source selected. For example, the program on the turbo-jet engine would require great emphasis of the relation of the noise energy produced to such factors as: (a) thrust; (b) fuel consumption; (c) engine rpm; (d) compressor design; (e) the combustion process, etc. The determination of the sub-sources in a turbo-jet engine and the evaluation of the relative contribution of each to the total noise produced is basic to any effort toward "source noise" reduction. Never-the-less the research required on the turbo-jet engine will fall into the same broad outline. If the program outlined for the aircraft appears complex and long this should serve only to emphasize the magnitude and complexity of the total program. The magnitude of the complete program can be visualized by recalling the number of operational aircraft and the different engines used with them. Yet this is only one of the three major sub-areas to be considered. The second of these sub-areas, research on the Intervening Media will now be outlined.

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2. Intervening Media:

Man rarely comes into direct contact with the vibratory energy source. If we consider noise, exposed personnel may be located a few inches from the source (aircraft and engine maintenance personnel) or they may be several miles from the source (community residents in areas near USAF Air Bases). If we consider mechanical vibration the exposed personnel may be separated from the source only by their clothing or they may be located many feet away with structures between them and the source. Usually the vibratory energy level is decreased on passage through these media so that they act as protective devices for man. Except for "source reduction" of vibratory energy level all practical methods for reduction and control of vibratory energy are applied to its transmission path through the intervening media. Because of this fact the properties of the media and their influence on the propagation of energy are practical matters of great importance. In outlining the research program two classes of media will be considered: (1) Natural Media; (2) Artificial (Man-Made) Media.

2.1. Natural Media:
Three sub-divisions of natural media are of interest.

2.1.1. Air
2.1.2. Water
2.1.3. Earth

In outlining the research program on the Media sound (noise) will be the form of vibratory energy considered and air will be selected as the example of Media because of its practical importance with respect to USAF operations. However, it should be remembered that the same general outline will apply to problems involving the energy of mechanical vibration or to problems concerned with other natural media.

2.1.1. Air
2.1.1.1. Still, Homogeneous Air Masses
2.1.1.1.1. Energy Propagation
2.1.1.1.1.1. Significance of Physical Properties of Air
2.1.1.1.1.2. Influence of Air Temperature
2.1.1.1.1.3. Influence of Water Vapor Content
2.1.1.1.1.4. Variation with Air Density
2.1.1.1.2. Energy Attenuation
2.1.1.1.1.1. Variation with Energy Wave Amplitude
2.1.1.1.1.2. Variation with Path Length
2.1.1.1.1.3. Variation with Temperature
2.1.1.1.1.4. Relationship to Viscosity
2.1.1.1.1.5. Variation with Water Vapor Content
2.1.1.1.1.6. Influence of Physical Properties of Air

Although data pertaining to still homogeneous air masses are fundamental the practical air masses with which we deal, the atmosphere, are rarely still and almost never homogeneous. Much additional information about the atmosphere is required.

2.1.1.2. The Atmosphere (Air)

It is assumed that the fundamental relations among sound propagation, sound attenuation and the parameters of air masses have been derived from studies under section 2.1.1.1. Under this section the research will be aimed toward determination of the influence of atmospheric dynamics and the way the source is operated on the data derived from studies of still, homogeneous air masses.

2.1.1.2.1. Meteorological Variables and Sound Attenuation and Propagation
- 2.1.1.2.1.1. Wind Velocity Gradients
- 2.1.1.2.1.2. Temperature Gradients
- 2.1.1.2.1.3. Turbulence
  - 2.1.1.2.1.3.1. Large Scale Turbulence
  - 2.1.1.2.1.3.2. Small Scale Turbulence
  - 2.1.1.2.1.3.3. Turbulence Versus Altitude

2.1.1.2.2. Latitude Factors Influencing Meteorology
- 2.1.1.2.2.1. Geographical Regions

2.1.1.2.3. Influence of Earth's Surface
- 2.111.2.3.1. Mountains vs Plains, etc.

2.1.1.2.4. Seasonal Variations
- 2.1.1.2.4.1. Characteristic Seasonal Meteorology

2.1.1.2.5. Operational Factors (Source)
- 2.1.1.2.5.1. Source Close to Earth's Surface
- 2.1.1.2.5.2. Source Far from Earth's Surface
- 2.1.1.2.5.3. Effects of Source Motion

The outline presented above covers only the more important features of the program on natural media. Many details will have to be fitted in as the work progresses. Other natural media will be important under special operational conditions. The other important group of media to be considered is artificial (man-made) media.

2.2. Artificial (Man-Made) Media:

Except for reducing the vibratory energy output of a source by redesign of the generating machine, practical sound control techniques alter the properties of the path the sound takes between the source and exposed personnel. The research program on "Artificial (Man-Made) Media" will be concerned, therefore, with the structural devices, equipment, buildings, etc. that are designed and installed between the source and man for the purpose of reducing the energy level of the sound field in which man works. The variety of such devices is nearly unlimited, since there are so many different situations in which sound control is necessary or desirable. In this outline the examples of sources to be considered are (a) turbo-jet engines and (b) jet powered aircraft. The sample outline will also be restricted to sound as the form of vibratory energy considered.

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2.2.1. General Techniques (Media) for Noise Control
- 2.2.1.1. Structures Affording Transmission Loss
  - 2.2.1.1.1. Single, massive wall or Structure
  - 2.2.1.1.2. Multilayered Walls or Structures
  - 2.2.1.1.3. Laminated Walls or Structures
- 2.2.1.2. Energy Absorbing Structures
  - 2.2.1.2.1. Metal, Glass or Natural Fiber Blankets, Boards or Bats
  - 2.2.1.2.2. Resonators
  - 2.2.1.2.3. Combinations of Resonators with Absorbing Blankets, etc
- 2.2.1.3. Structures to Direct Radiation
  - 2.2.1.3.1. Stacks, Chimney and Ducts
  - 2.2.1.3.2. Reflecting Walls or Surfaces
- 2.2.1.4. Structures and Buildings Combining Tranamission Loss, Absorption and Directed Radiation
  - 2.2.1.4.1. Engine Test Buildings
  - 2.2.1.4.2. Buildings to Exclude Outside Noise

2.2.2. General Properties of Sound Control Materials
- 2.2.2.1. Mechanical Properties
  - 2.2.2.1.1. Mechanical Strength
  - 2.2.2.1.2. Resistance to Temperature
  - 2.2.2.1.3. Resistance to Humidity
  - 2.2.2.1.4. Resistance to Cleaning Processes
- 2.2.2.2. Acoustical Properties
  - 2.2.2.2.1. Absorption Capacity
  - 2.2.2.2.2. Transmission Attenuation
- 2.2.2.3. Fabrication of Complex Structures
  - 2.2.2.3.1. Ease of Fabrication
  - 2.2.2.3.2. Useful Life
  - 2.2.2.3.3. Ease of Maintenance

2.2.3. Classes Sound Control Structures
- 2.2.3.1. Engine Test Buildings
  - 2.2.3.1.1. Research Facilities
  - 2.2.3.1.2. Production Type Facilities
  - 2.2.3.1.3. Portable Engine Test Units
- 2.2.3.2. Aircraft Engine Run-up Facilities
  - 2.2.3.2.1. Single Engine Aircraft
  - 2.2.3.2.2. Multi-engined Aircraft
- 2.2.3.3. Wind Tunnels and Special Facilities
  - 2.2.3.3.1. Small Units
  - 2.2.3.3.2. Large Facilities
- 2.2.3.4. Anechoic (Absorbing) Rooms & Chambers
  - 2.2.3.4.1. Large, Accustical Chambers
  - 2.2.3.4.2. Studio Type Rooms
  - 2.2.3.4.3. Audiometric Test Rooms
  - 2.2.3.4.4. Small, Instrument Testing Chambers
- 2.2.3.5. Personally Worn Sound Attenuating Devices
  - 2.2.3.5.1. Ear Plugs
  - 2.2.3.5.2. Noise Excluding Helmets
  - 2.2.3.5.3. Other Noise Excluding Personal Equipment

2.2.4. Evaluation of Noise Control Installations
2.2.4.1. Relative Effectiveness of Specific Design
2.2.4.2. Relative Cost and Cost vs Effectiveness
2.2.4.3. Maintenance Cost
2.2.4.4. Overall Relative Value of Specific Design
2.2.5. Development of New Materials and New Designs
2.2.5.1. Acoustical Materials Having Improved Mechanical Properties
2.2.5.2. Acoustical Materials with Improved Energy Reducing Properties
2.2.5.3. Improved Designs for Specific Noise Control Jobs

The research program outlined above covers only the major features of selected parts of the problem area pertaining to media. Similar programs will be required for problems involving mechanical vibrations and other media. When we possess sufficient knowledge of the vibratory energy source level and of the energy loss in the medium, we can, when we have defined man's response in terms of energy level, specify the reduction in energy required to assure man's safety, health and performance efficiency. We shall now outline a program for the third major sub-area of research - the area pertaining to man.

3. Man:

In the system, Vibratory Energy - Media - Man, the key element is Man. The primary USAF requirements for the control of noise and vibration arise because of the undesirable action of this energy on Man (exposed personnel). Certain vibratory energy levels are direct hazards and produce immediate or delayed pathology. Other levels of energy interfere with Man's normal physical, physiological and/or psychological functions and are, therefore, indirectly hazardous. Still other levels of energy are <u>not acceptable</u> because they induce fear, create annoyance, prevent rest, relaxation and sleep or they are unacceptable because of their effects on Man's possessions, such as, real estate, domestic animals, etc.

Some of these effects of the vibratory energy are important because they produce undesired effects on personnel of the USAF. Other effects of the vibratory energy are important because of the undesirable reactions to USAF operations they create among residents of communities located near USAF Air Bases.

To predict the effect on man of noise and vibration, produced by USAF Sources, and to specify the required reduction in energy level quantitative data which specify human response, in terms of energy level and frequency distribution of energy, must be obtained. Such data are required for each human functional system and for the entire body as a mechanical system. The outline of the research program on <u>Man</u> shall be limited to major aspects of the problem area, as was the case for the other two (2) elements of the system (Vibratory Energy Sources - Media - Man).

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Sound (noise) will be the form of vibratory energy considered in outlining the research program. The following aspects of the problem area are significant: (1) Mechanical Properties of the Body Surface, the Tissues and Sensory Receptors; (2) Functional Properties of Sensory Systems; (3) Complex Human Reactions.

3.1. Mechanical Properties of Elements of the Human Body

The mechanical properties of the structural elements of the human body determine: (a) the quantity of vibratory energy that enters the body; (b) the distribution of the energy inside the body; (c) the site and mechanisms of energy dissipation. Research is required in the areas outlined:

- 3.1.1. Significant Mechanical Properties (applicable to all Structural Elements)
  - 3.1.1.1. General Mechanical Structure
  - 3.1.1.2. Elasticity
  - 3.1.1.3. Viscosity
  - 3.1.1.4. Compressibility
  - 3.1.1.5. Mechanical Impedance - Transfer Characteristics
  - 3.1.1.6. Absorption Coefficients - for Vibratory Energy
  - 3.1.1.7. Attenuation Constants - for Vibratory Energy
- 3.1.2. Body Elements (Structures) of Significance
  - 3.1.2.1. General Body Surface (Skin Structure)
    - 3.1.2.1.1. Surfaces overlying soft tissues
    - 3.1.2.1.2. Surfaces overlying hard tissues
  - 3.1.2.2. Subsurface Body Tissues
    - 3.1.2.2.1. Muscle tissue
    - 3.1.2.2.2. Fatty tissues
    - 3.1.2.2.3. Bones, ligaments, tendons
    - 3.1.2.2.4. Tissues composing internal organs
  - 3.1.2.3. Special Receptors (sensory)
    - 3.1.2.3.1. The ear (hearing organ)
      - 3.1.2.3.1.1. Middle ear
      - 3.1.2.3.1.2. Inner ear and associated structures
    - 3.1.2.3.2. General Surface or Sub-surface Receptors
      - 3.1.2.3.2.1. Pressure, tactile receptors, etc. in skin
      - 3.1.2.3.2.2. Thermal receptors (skin)
    - 3.1.2.3.3. Proprioceptive Receptors
      - 3.1.2.3.3.1. Vestibular apparatus
      - 3.1.2.3.3.2. Muscle, tendon, joint receptors
    - 3.1.2.3.4. Internal Organ Receptors
      - 3.1.2.3.4.1. Stretch receptors (internal organs)
      - 3.1.2.3.4.2. Pain receptors
      - 3.1.2.3.4.3. Special vascular system receptors

3.2. Functional Properties of Sensory Systems:
- 3.2.1. Hearing Organ - Ear:
  - 3.2.1.1. Auditory sensitivity (hearing thresholds)
    - 3.2.1.1.1. Sensitivity vs frequency and frequency range
    - 3.2.1.1.2. Sensitivity for speech signal (speech threshold)
  - 3.2.1.2. Loudness Perception
    - 3.2.1.2.1. Loudness vs sound pressure level
    - 3.2.1.2.2. Loudness vs frequency
    - 3.2.1.2.3. Loudness and complex sounds, speech and noise
  - 3.2.1.3. Pitch Perception
    - 3.2.1.3.1. Pitch vs frequency
    - 3.2.1.3.2. Pitch vs sound pressure level
  - 3.2.1.4. Perception of Speech Signals
    - 3.2.1.4.1. Frequency and intensity range of speech signals
    - 3.2.1.4.2. Speech intelligibility
    - 3.2.1.4.3. Masking speech vs industrial noise
    - 3.4.1.4.4. Speech interference criteria (noise)
  - 3.2.1.5. Basic Physiology of the Inner Ear
    - 3.2.1.5.1. Activation of the neural element
    - 3.2.1.5.2. Relation of mechanical to neural response
  - 3.2.1.6. Effects of Intense Sound
    - 3.2.1.6.1. Intensity of sound vs damage
      - 3.2.1.6.1.1. Temporary deafness
      - 3.2.1.6.1.2. Permanent deafness
      - 3.2.1.6.1.3. Industrial noise and deafness
      - 3.2.1.6.1.4. Damage risk criteria
  - 3.2.1.7. Complex Psychic and Physiological Responses
    - 3.2.1.7.1. Startle reaction
      - 3.2.1.7.1.1. Parameters of sound field responsible for
    - 3.2.1.7.2. "Fear reaction"
      - 3.2.1.7.2.1. Parameters of sound field responsible for
    - 3.2.1.7.3. Necessary lapses, etc.
      - 3.2.1.7.3.1. Specification of sound field producing
- 3.2.2. Posture, Body Position, Body Motion Systems
  - 3.2.2.1. Vestibular apparatus
    - 3.2.2.1.1. Disturbances to posture vs vibratory energy
    - 3.2.2.1.2. Disturbances to locomotion vs energy level
    - 3.2.2.1.3. Effect on internal organ systems vs energy level
  - 3.2.2.2. Proprioceptive System
    - 3.2.2.2.1. Effects of energy on sense of body position
    - 3.2.2.2.2. Interference with neuro-muscular coordination - relationship to energy levels
    - 3.2.2.2.3. Disturbances to locomotion vs energy level
- 3.2.3. General Surface Receptor Systems
  - 3.2.3.1. Pressure sensation vs energy level
  - 3.2.3.2. Heat sensation vs parameters of energy field
  - 3.2.3.3. Pain sensation vs parameters of energy field
  - 3.2.3.4. Sensation of general body vibration vs energy field

3.2.4. Internal organ receptor systems
3.2.4.1. Response of vascular systems vs energy level
3.2.4.2. Gastro-intestinal responses vs energy level

3.3 Complex Human Reactions

Many of the important effects of noise on man will be produced through a complex response or reaction which is determined by the action of the energy on one or more receptor systems. Such reactions will influence work performance, mental attitude, sense of well being and many other general functions or states. The quantitative relationship existing among the parameters of the sound field and these complex responses must be established.

3.3.1. Voice Communications
3.3.1.1. Relation to function of hearing
3.3.1.2. Relation to speech signal formation
3.3.2. Startle Reaction
3.3.2.1. Significant parameters for initiating reaction
3.3.3. Fear Reaction
3.3.3.1. Relationship to parameters of sound field
3.3.3.2. Relationship to "conditioning"
3.3.4. Neuro-Muscular Coordination
3.3.4.1. Precision manual operations
3.3.5. Nausea, Vomiting Reaction Complex
3.3.6. Mental attitude toward assigned duties
3.3.7. Mental or personality attitudes
3.3.7.1. With respect to co-workers
3.3.8. Sensations of generalized body vibration
3.3.9. Social or antisocial attitudes and actions

In this duscussion of the research program pertaining to man, sound has been the form of vibratory energy considered. The same kinds of data are required when the vibratory energy is derived from mechanical vibrations. Therefore, essentially the same outline of work required can be applied to the problems involving mechanical vibration. However, certain basic information, such as data pertaining to physical and mechanical characteristics of the body and its tissues, are applicable to problems involving both forms of vibratory energy. In other cases the data obtained with respect to sound waves can be applied directly to problems involving mechanical vibration, provided account is taken of any differences in efficiency of transfer of the energy into the body that exists between the two forms of vibratory energy.

Interrelations Among the Major Sub-Programs:

The research program pertaining to the system, Vibrating Energy Sources - Media - Man, is outlined under three major sub-programs. Each sub-program is associated with one major component of the system. However, many practical problems can be solved only by comparing, correlating and integrating data developed by two or more of the sub-programs. For example a determination of the effectiveness of an engine exhaust muffler, as a device to protect personnel, is based on the following sets of data: (1) quantitative data specifying the engine as a noise energy source; (2) quantitative data stating the attenuation of the noise energy by the muffler; (3) quantitative data describing the maximum noise energy levels that are compatible with man's performance of his assigned tasks. In this case; source energy level minus the energy absorbed by the muffler (attenuation) equals the noise energy to which man is exposed. Comparing this level with the 'level compatible with performance' permits one to state that the muffler is effective or non-effective as a protective device. On the other hand, subtracting the permissible noise energy level (stated in terms of human performance capability) from the source noise energy level specified the noise energy reduction (attenuation) the muffler must introduce. This data constitutes design criteria for the muffler. Numerous examples of these relatively simple integrations of data could be cited. However, one rather complex problem area will now be analyzed to further illustrate the interrelations among the sub-programs. Planning an Air Base for adequate noise control is the complex problem area to be considered. The important elements of this problem are outlined below:

Criteria for Air Base Planning:

In planning an Air Base to provide the noise control measures required to assure adequate protection for personnel employed on the base and to assure satisfactory relations with persons residing outside the base quantitative data, pertaining to at least the following areas, are required:

1. Noise Energy Sources:

The noise field produced by the following major noise sources must be quantitatively determined:

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1.1. All airplanes under ground operating conditions
  1.1.1. Maintenance operations
  1.1.2. Taxiing operations
  1.1.3. Pretake-off operations
1.2. All airplanes - during flight operations
  1.2.1. Take-off - including climb to altitude
  1.2.2. Approach and landing operations
  1.2.3. All other low altitude operations near the base
1.3. Engine and propeller test cells and stands
  1.3.1. As noise sources - affecting base areas outside the test stands
  1.3.2. As noise sources - affecting areas outside the base
  1.3.3. As noise sources - affecting operation of the facility itself
1.4 Aircraft ground support equipment
  1.4.1. As noise sources - affecting operating personnel
1.5 General Air Base maintenance equipment
  1.5.1. As noise sources - affecting operating personnel

2. Media - Transmitting Noise Energy:

Quantitative specification of the reduction in noise energy introduced by each of the following media is necessary:

2.1 The air
  2.1.1. Normal - "air attenuation of noise energy" in relation to
    2.1.1.1. Aircraft in flight
    2.1.1.2. Aircraft operated on ground
    2.1.1.3. Operation of all ground installations and equipment
  2.1.2. Influence of weather states on "air attenuation of noise"
    2.1.2.1. Motion of air - winds, atmospheric turbulence
    2.1.2.2. Temperature gradients
    2.1.2.3. Variation of humidity
    2.1.2.4. Low cloud formation, etc.
2.2. Structures or buildings - housing test cell operations, etc.
  2.2.1. Special mufflers - external noise control
  2.2.2. Special internal structures - internal noise control
2.3. Structures or buildings - housing offices and other regular operations
  2.3.1. Offices and warehouses
  2.3.2. Quarters, barracks, etc.
  2.3.3. Hospitals

3. Man:

Noise levels consonant with specific assigned duties must be quantitatively stated as must be the levels that are acceptable in terms of every-day living. These quantitative data are required for the following group of personnel.

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3.1 Air Base Personnel
- 3.1.1. Personnel at work - levels consistent with effective performance of assigned duties
  - 3.1.1.1. Aircraft and engine maintenance personnel
  - 3.1.1.2. Test cell operating personnel
  - 3.1.1.3. General office personnel
  - 3.1.1.4. Machine shop and warehouse personnel
- 3.1.2. Other personnel on Air Base
  - 3.1.2.1. Personnel in quarters
  - 3.1.2.2. Personnel in hospitals, etc.

3.2 Non-Air Base personnel (community residents, etc.)
- 3.2.1. Personnel at work - noise level acceptable with respect to each job or duty.
- 3.2.2. Personnel in homes, recreational activities, etc. - noise levels compatible with these various activities
- 3.2.3. Corollary factors - influencing community acceptance of noise
  - 3.2.3.1. Effects of noise on animals possessed by community residents
  - 3.2.3.2. Effects of noise on real estate
    - 3.2.3.2.1. Residences - noise induced vibration of general structure
    - 3.2.3.2.2. Residences - noise induced vibration of building furnishings
  - 3.2.3.3. Social, economic and political factors - influencing attitude towards USAF in general

Examination of this abbreviated outline of factors that must be considered in evaluating the relation of noise to Air Base planning indicated the complexity of the problem. To determine the distance that should separate a community and an aircraft in flight the following data are required: (a) quantitative data on the noise levels produced by the aircraft; (b) quantitative data on the noise energy absorbed by the air; (c) a quantitative statement of the probable variations of this energy loss under different weather conditions; (d) quantitative data on the noise level acceptable to members of the community - to be determined in relation to each specific activity to be carried out by each community resident; (e) quantitative data about the influence of aircraft operations - such as total number of flights daily, hours of the day during which flights occur, frequency distribution of flights throughout the day, etc. By intercomparing these data and evaluating the effects of their variation general rules can be established for locating the Air Base, orienting its runways and planning its general layout to avoid or minimize responses of the community to the noise.

To plan an Air Base to assure maximum safety to personnel, to assure maximally effective performance by USAF personnel and to assure acceptable conditions for living on the base, many other sets of data

must be considered. Thus, planning an Air Base for effective noise control requires the utilization of nearly all the quantitative data from the three sub areas of the research program. The problem, Planning an Air Base for adequate control of vibratory energy (noise and vibration), illustrates the more complex interrelations among the three Sub-Programs of the general research program. In general, the effectiveness of the effort to obtain adequate noise control will be determined by the reliability of the sets of basic quantitative data available for use.

The CHAIRMAN. The committee has one more session scheduled for tomorrow morning. We have three witnesses to hear at that time. It should be a very interesting session.

One of the witnesses is from the Pratt & Whitney Division of the United Aircraft Corp.

The other is the Administrator of the Federal Aviation Agency.

The third witness to be heard is Mr. Spano, director of Polysonics, Inc., of Washington.

If there is no objection, then, we will adjourn until tomorrow morning at 10 o'clock.

Again, thank you very much, Doctor.

(Whereupon, at 12:30 p.m., the committee adjourned, to reconvene at 10 a.m., Thursday, August 25, 1960.)

NOISE: ITS EFFECT ON MAN AND MACHINE

THURSDAY, AUGUST 25, 1960

HOUSE OF REPRESENTATIVES,
COMMITTEE ON SCIENCE AND ASTRONAUTICS,
SPECIAL INVESTIGATING SUBCOMMITTEE,
Washington, D.C.

The subcommittee met in room 214–B, New House Office Building, at 10 a.m., Hon. Overton Brooks, chairman, presiding.

The CHAIRMAN. The committee will come to order.

We have three witnesses this morning. The first witness is Mr. Bernard A. Schmickrath, engineering manager of Pratt & Whitney Division, United Aircraft Corp., Hartford, Conn.

The second witness is Gen. Elwood R. Quesada, Federal Aviation Agency.

And then we have Mr. Bart Spano, director of Polysonics, Inc., Washington, D.C.

We are pleased this morning to have as our first witness, Mr. Schmickrath, who, by the way, is from Connecticut.

Am I correct?

Mr. DADDARIO. That is right, Mr. Chairman.

The CHAIRMAN. Mr. Daddario, do you have any remarks you want to make at this point?

Mr. DADDARIO. Mr. Chairman, I would be pleased to make a few remarks.

During these hearings the subcommittee has chosen a field of major concern to the urban communities of the eastern seaboard in checking on the progress and learning about noise and its effect and possible controls.

Much has been done in recent years to explore the qualities, characteristics, and utility of sound. At the same time, as we become more crowded in our society by an expanding population, by better communications, and by more rapid means of transportation, we become aware of the harm and annoyance that sound can cause.

Such cities, among many, as Hartford, Washington, Baltimore, and New York, have been concerned for many years about the noise of high-speed aircraft, military as well as civil. Airports have been moving out of town rather than inconvenience their neighbors by excessive noise. But they can't move too far or the convenience of transportation they offer—and the importance of the defense they provide—will be lost. The solution has been obviously to attack this question of sound and conquer it.

For many years, scientists in the research and development laboratories at the United Aircraft Corp. in my district have been aware of the difficult problems of noise, especially in connection with jet engines.

I have spoken in the past of the growth of these companies, their civic responsibility and their alert approach to the opportunities and hazards of the future.

The research done in control of engine noises has been a striking example of the forward thinking which has been done. Several of the engineers at the East Hartford laboratories in Connecticut have been pioneers in this work.

I am happy, Mr. Chairman, to present to this committee the engineering manager of Pratt & Whitney Division of United Aircraft, Bernard A. Schmickrath. A veteran of 22 years with Pratt & Whitney's engineering department, he was formerly general manager of the Connecticut Aircraft Nuclear Engine Laboratory operated by Pratt & Whitney to develop an indirect cycle propulsion system for a nuclear-powered aircraft.

In his present position, he continues to have that responsibility. A graduate of the University of Washington, he is also a veteran of the U.S. Marine Corps.

I am pleased, Mr. Chairman, to have Mr. Schmickrath here, and I am sure that what he will tell us will be of great importance to the hearings now being held.

The CHAIRMAN. Mr. Schmickrath, you have been well introduced by our distinguished colleague from Connecticut. You have a prepared statement. I think the members of the committee have a copy of it. We will ask you to proceed, sir.

STATEMENT OF BERNARD A. SCHMICKRATH,[8] ENGINEERING MANAGER, PRATT & WHITNEY AIRCRAFT DIVISION, UNITED AIRCRAFT CORP.

Mr. SCHMICKRATH. Yes, sir. I would like to read this statement, with your permission. During the statement, we would like to play a sound tape to illustrate and prove a point made in the statement.

The CHAIRMAN. Is it intense sound? Do we need any cotton?

Mr. SCHMICKRATH. No, it won't be long enough to bother you.

The CHAIRMAN. All right. Fine.

Mr. SCHMICKRATH. Before addressing myself to the subject being considered by this committee, I would like to express the appreciation of Pratt & Whitney Aircraft Division of United Aircraft Corp. for the opportunity of being represented here today. We recognize the importance of this problem and feel privileged in being allowed to contribute to these proceedings.

It is essential, in our view, to recognize the fact that the aircraft noise problem did not begin with the introduction of jet aircraft. Not long after the Wright Brothers established the practicality of powered flight, pioneer pilots, as they flew over farmlands, were accused of disrupting habits of livestock.

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[8] Bernard A. Schmickrath is engineering manager of Pratt & Whitney Aircraft Division of United Aircraft Corp., East Hartford, Conn. He has held this post since June 1958.

A veteran of 22 years in Pratt & Whitney Aircraft's engineering department, Mr. Schmickrath previously served as assistant engineering manager and as general manager of the Connecticut Aircraft Nuclear Engine Laboratory. CANEL is engaged in the development of an indirect-cycle propulsion system for a nuclear-powered aircraft. In his present position, Mr. Schmickrath continues to have prime responsibility for the nuclear engine program.

Mr. Schmickrath joined Pratt & Whitney Aircraft as a test engineer after his graduation from the University of Washington in 1938. He was promoted to development engineer and chief of experimental test laboratories before being named assistant chief engineer in charge of the aircraft nuclear project. During 1944 and 1945 he served with the United States Marine Corps.

As internal combustion engines became more powerful and aircraft larger, faster, and more plentiful, the noise problem began to affect those people living near airports and near installations testing aircraft and engines.

The advent of the jet aircraft has intensified the problem because of the greater energies involved. It has also intensified the efforts on the part of everyone concerned to find solutions which will be acceptable to the affected communities without seriously arresting the progress of the air transport industry.

The current noise problem, for purposes of discussion, can be separated into two parts, the one dealing with noise that is unavoidable in the development of rockets and rocket-propelled missiles, and the other dealing with the noise of manned jet aircraft.

Pratt & Whitney Aircraft's rocket development plans have met any possible community objections by locating test activities in our remote facilities in the Florida Everglades 25 miles from West Palm Beach.

Since Pratt & Whitney has been able to solve our rocket noise problems by extreme remote location, the other rocket manufacturers can undoubtedly give more information on this subject.

The noise from jet aircraft is a completely different problem. Jet aircraft must land on and take off from airports close to populated areas. They must be scheduled to serve the traffic needs economically, efficiently and they must be operated at any time of the day or night. This is particularly true if they are to be utilized in cargo transport, an activity which many believe will outstrip passenger travel in volume and dollar value not many years ahead.

As the use of jet aircraft continues to increase so does this noise problem. No group realizes its importance more keenly than all of the aircraft industry and those branches of the Government most closely concerned with aeronautics.

When we stop to think, we realize that the release of energy in the atmosphere is always accompanied by noise. It does not seem to make any difference whether man or nature is responsible. It makes a marked difference, however, in public reaction.

I think it is fortunate that nature alone is responsible for thunderstorms for if industry had drawn a hand in their occurrence I am reasonably sure that public reaction would be quick and violent.

The noise produced by jet-powered aircraft presently in service is of concern to the neighbors of airports on two occasions: First, when an aircraft climbs after takeoff; secondly, when it approaches at low altitude for landing, The engineering problems involved in alleviating the noise produced in each case are very different.

May we first consider the takeoff noise.

Jet aircraft travel much faster than the type to which we had previously become accustomed. The added power required to achieve this speed means a greater rate of energy release on takeoff and accompanying greater noise. This noise is not generated inside the engine but around the high-velocity jet stream of air discharged from the exhaust to the rear.

The aircraft industry, with the aid of specialists in acoustics and with the aid and cooperation of Government agencies concerned, has carried on a vigorous program of noise research and noise suppressor development for many years.

Pratt & Whitney Aircraft started intensive work on jet-noise suppression in 1953, and has established extensive acoustic and research facilities.

In addition, the airframe builders have been quite successful in reducing the exhaust noise through the use of special nozzles which change the character of the jet airstream as it leaves the engine. All current operating aircraft have these nozzles as standard equipment.

This method has certain important disadvantages. It reduces the power, adds weight, and increases fuel consumption. To the airplane operator this means loss in payload, loss in performance, and increases in costs per ton- and/or passenger-mile.

The exhaust noise may be effectively reduced, and efficiency gained, by reducing the velocity of the jet airstream through the use of the bypass, ducted fan, or turbofan principle. Engines of this design remove additional energy from the exhaust gas, thus slowing the jet velocity. This energy is used to operate a fan which draws extra air into the inlet and blows it toward the rear, thereby providing extra power.

At the same time that the conversion of an airplane from jet power to turbofan power reduces the exhaust noise generation, it increases the maximum thrust available for takeoff and initial climb. Hence, the aircraft may be able to pass over the neighborhood at a higher altitude. This double benefit of turbofan-type engines will reduce the takeoff noise an appreciable amount.

We are convinced that the development and use of bypass or ducted fan engines will go a long way toward alleviating the takeoff noise problem. This type of Pratt & Whitney Aircraft engine is now in production and is being installed in both Boeing and Douglas aircraft. In addition there will be an extensive retrofit program on present aircraft.

A noise evaluation scale has been devised by the acoustical consulting firm of Bolt Beranek & Newman called perceived noise in decibels, or PNdb for short. This scale has been used with success by the industry to measure the subjective reaction of the average person to the type of noise produced during takeoff.

When we consider the problem of noise on low-level approach, which currently seems to cause the majority of complaints, this PNdb measurement scale no longer proves adequate.

During the approach, much lower thrust is used to fly the airplane along the approach flightpath than is used during the following takeoff. This results in the roar of the exhaust being greatly decreased, and the noise heard is predominantly the whine of the engine compressor.

Methods for reducing this whine have been found which are numerous and very effective. Internal design of the engine and design of the air inlet and fan-discharge ducts can have great influence upon this noise, and we believe will provide future aircraft that will be decidedly less annoying on approach than those currently in operation.

This brings us to the question of evaluting the annoyance caused by jet transport operations over a given community. The PNdb scale successfully designed for jet-exhaust noise does not measure adequately noises containing the high-pitched notes of compressor whine on approach.

In order to illustrate this we have prepared a tape comparing two noises of different character, but reproduced at equal loudness on the

PNdb scale. One is the noise from the inlet of a jet engine currently powering long-range transports in a regular airline service. The other is the noise from the inlet of a turbofan engine especially designed to reduce the high-pitched whine, and in addition fitted with an aircraft inlet duct having effective acoustic absorption.

Listen to these two noises at identical PNdb levels, and form an opinion as to whether or not they are equally annoying.

Mr. Chairman, thank you. And I think Congressman Daddario should move, too, while our people turn this on.

The CHAIRMAN. Is the chairman in the right position?

Mr. SCHMICKRATH. You are all right, sir.

The CHAIRMAN. All right.

(The tape was played, as follows:)

VOICE ON TAPE. This tape has been prepared by Pratt & Whitney Aircraft to illustrate the difference in annoyance of two engine noises when reproduced at the same PNdb level. Both noises are typical of that heard from the inlet as the airplane approaches with the engines set at 4,000-pound thrust. First, the inlet noise of a Pratt & Whitney Aircraft JT-4 turbojet engine, as currently used in long-range jet transports.

[Play 5-second sample.]

Second, the inlet noise of a Pratt & Whitney Aircraft JT-3D turbofan engine as developed to reduce the whine and equipped with a sound-absorbing aircraft inlet.

[Play 5-second sample.]

For better comparison these two noises are now alternately repeated several times without interruption.

[About 30 seconds of alternate noises.]

Mr. SCHMICKRATH. Everyone here, I think, can understand why we don't like the high-pitched whine. In listening to these recordings I am sure you became aware of the marked difference between the noises you heard. The difference in annoyance is even more pronounced when the engines are themselves demonstrated side by side, as they were at East Hartford for staff representatives of this committee, FAA, NASA, aircraft, and airline groups.

However, under present methods of measuring aircraft noise levels these two distinctly different sounds are judged to be the same. Therefore, I cannot emphasize too strongly our conviction that new standards of noise evaluation must be formulated.

Should a situation develop, as it well may, that laws, ordinances, or regulations are enacted based on present standards, jet aircraft operations could be severely hampered. It is in this area where we feel the Government, through the Bureau of Standards, the FAA, the NASA, or some other impartial group, can be of enormous help in formulating realistic and workable standards of overall noise evaluation.

As we understand it, the FAA has not attempted to establish acceptable noise parameters so much as to emphasize methods of operation in airport approaches and takeoff to reduce noise disturbances as much as possible.

This is bound to be helpful in the overall problem but the establishment of a standard measurement code is imperative before any organization can do a technically sound job.

It is not being pessimistic to say that there will always be problems in an industry as dynamic as aviation. This truth has been emphasized by the committee in its question concerning the noise problem in supersonic transports.

It is difficult for an engine manufacturer to be precise in a discussion of air transports not yet designed. We already have operated engines under the required supersonic conditions.

Certainly there is one hopeful thought—noise disturbance from supersonic transports may be less of a problem than it is today simply because these new aircraft may have a faster rate of climb and will fly higher over populated areas than they do today. This is a hope rather than a prediction or a solution. We cannot disregard either today's problems or those that are coming up in the future.

In our work on technical and scientific projects we have always been greatly helped by probing deeply into the nature of the phenomena with which we are dealing. This we will continue to do on the noise problem. Each day, through studies by Government agencies and qualified research groups, more is being learned about the character of noise and its effect on people.

Certainly, types and kinds of noise produce varying reactions from individuals subjected to it. As we learn more about the basic cause and effect of noise, I feel sure that we will be able to apply this knowledge gainfully in the reduction of sound levels that are most irritating to the human system.

Our need now is for the confidence and understanding of the public as we continue to combine efforts in the aircraft industry to seeking solutions. The fact that this committee is sitting in consideration of this problem will, I believe, prove of immeasurable value in achieving this understanding.

In closing, I would like to repeat that engine noise is being given serious consideration in the design of Pratt & Whitney aircraft engines. In fact, this problem has and will continue to be one of our major engine design parameters.

Thank you, sir.

The CHAIRMAN. That is a very excellent statement. I am sure when we consider the illustration which you have given us in noise from the sound equipment that you demonstrated, it is going to be of great importance to the committee members.

I think I draw from your statement the fact that you feel that some other authority, save the manufacturer, should be given the responsibility for setting forth certain criteria which the engine designers and manufacturers should meet in handling this problem of vexing noises.

Mr. SCHMICKRATH. Mr. Chairman, we definitely feel that way. We don't think that it can be a single group criteria. We don't think it will be accepted. We think it should be an impartial group, using all the various aeronautics people to end up with a situation and a set of criteria that are acceptable to all.

The CHAIRMAN. Now, you suggest several agencies. Do you have any preferences among those agencies?

Mr. SCHMICKRATH. The only preference that I have is that they be impartial.

The CHAIRMAN. Yes. I think that is extremely important.

Mr. SCHMICKRATH. Right.

The CHAIRMAN. Impartiality would certainly play a part in the manufacturing of airplanes and airplane engines.

We have this morning General Quesada here representing the FAA.

Now, the FAA was not mentioned in your statement, save later on as a reference to the means of applying these criteria, isn't that correct?

Mr. SCHMICKRATH. That is right, sir.

The CHAIRMAN. That is the way you feel about the FAA.

Mr. SCHMICKRATH. No, I don't think that is necessarily the way we feel about them. This is the one point—I named a number of agencies just as an illustration.

The CHAIRMAN. Let me ask you one or two questions.

Would you explain in more detail the concept of the turbofan engine? We heard the noise, but tell us just a little bit more about the engine.

Mr. SCHMICKRATH. Well, let's start with the basic J–57 engine. I think everyone is familiar with the B–52 which uses the J–57. The Boeing 707, and Douglas DC–8 also use the commercial version of the J–57 engine.

If we add an extra stage to the turbine of the engine, this turbine takes energy from the exhaust gas, and if we use this energy to drive additional compressor or fan stages at the front of the engine, we handle a greater amount of airflow at a lower velocity. In this way we get more thrust, better specific fuel consumption and a lower jet velocity, which reduces the exhaust noise.

The CHAIRMAN. Do you think that it is possible to set forth criteria against the design for curbing maximum noises?

Mr. SCHMICKRATH. I think it would be useful, but I don't think at the present time with the standards of measurement we have that we can set a realistic criterion.

The CHAIRMAN. The illustration that you gave us this morning, illustrates that you have the same intensity noise but entirely different types of sound?

Mr. SCHMICKRATH. They sound entirely different to the person that the airplane is flying over.

The CHAIRMAN. So your criteria would have to differentiate between different types of sound?

Mr. SCHMICKRATH. I am sure that with the right amount of effort on it that they can end up with a useful criteria that the engine manufacturers can use.

The CHAIRMAN. If standard noise design criteria were developed by a Government regulatory agency, would it assist the airframe and jet engine manufacturer in designing air transports of the future, such as the one we had hearings on?

Mr. SCHMICKRATH. If they had the right standards of measurement to start with, yes, I think it would be useful.

The CHAIRMAN. Now, those criteria should include, should they not, consideration of property damage and health of the local people that might be affected, and matters of that character.

Mr. SCHMICKRATH. That is somewhat beyond my field. The only criteria that I could know anything about is what we would set for the design of the engine. We don't study the other areas.

The CHAIRMAN. The airframe.

Mr. SCHMICKRATH. That is right, we are the engine people.

The CHAIRMAN. I have had the pleasure of visiting your plant although it has been some time ago. I was impressed with what you have there in the way of facilities and your ability to turn out engines of greatest efficiency.

How much money has your company invested in this problem?

Mr. SCHMICKRATH. This question divides itself into two parts. The first on the facilities part, we have invested slightly over $1,400,000 in special facilities just for acoustic work. This does not include any of the regular equipment that is available, such as floorspace, IBM machines, machine tools. That is available to use on this type of project.

In the development costs we don't, accountingwise, divide the development costs within a given engine development group down into individual development problem areas. In other words, in the development of an engine we have 100 different problems, specific fuel consumption, thrust, weight, durability. Noise is one of those problems.

We have no way to pick out the amount of money we spent just for noise. There are only very few times that we would ever run an engine just to investigate only one problem.

The CHAIRMAN. Now, does Pratt & Whitney have an acoustical laboratory?

Mr. SCHMICKRATH. Yes, sir. We have furnished your staff with pictures of this laboratory, and this facility constituted the $1,400,000 investment that I just quoted.

The CHAIRMAN. You retain consultants in the field of noise and bioacoustics?

Mr. SCHMICKRATH. Yes, sir. I can tell you who some of them are.

We have used Bolt Beranek & Newman, and Armour Research in the design of soundproofing for test houses, because we have had a community relation problem with all our engines running in East Hartford.

We use a gentleman from Johns Hopkins, Dr. Kovasgnay.

We use Dr. Ingard and Dr. Pridemore-Brown from MIT.

We use a small group called the United Acoustics group who do laboratory work on soundproofing inlets.

And as we go along, we use any other people that are specialists in the field.

The CHAIRMAN. From time to time you make changes.

Mr. SCHMICKRATH. That is right, sir.

The CHAIRMAN. What is your opinion of the voluntary noise abatement program of the FAA for 1960?

Mr. SCHMICKRATH. I don't have any fixed opinion on it, Mr. Chairman.

The CHAIRMAN. You have an open mind on it?

Mr. SCHMICKRATH. I have an open mind.

The CHAIRMAN. Do you feel that the NASA is devoting enough time and money to this problem?

Mr. SCHMICKRATH. We feel they are devoting quite a bit of effort to it, yes, and it has been very helpful to us.

The CHAIRMAN. What do you feel can best be done to help in solving this problem?

Mr. SCHMICKRATH. I think the thing we need right now is this standard set of measurements so that we know what we are actually shooting for.

The CHAIRMAN. And that goes back to the question of the formulation of criteria, and they should set forth the standard measurements that you referred to?

Mr. SCHMICKRATH. That is right, sir.

The CHAIRMAN. Now, any questions from members? I will recognize anyone.

I recognize Mr. Fulton.

Mr. FULTON. Should Congress pass a law limiting noise to tolerable levels on a standard of measurements set by the U.S. Bureau of Standards?

Mr. SCHMICKRATH. First to answer your question, sir, we need the standard of measurement. Now, whether the Bureau of Standards should set it or not, I don't know.

Mr. FULTON. But suppose that there is a standard of measurement that is adequate, set by some Federal Government agency, the question then assumes that this has been done and raises the problem: should Congress pass a law limiting noise and sound in certain situations to a tolerable level based on a standard set of measurements set by some U.S. Government agency?

I thought you would recommend that the U.S. Bureau of Standards do it.

Mr. SCHMICKRATH. No, sir. I suggested an impartial agency. I didn't care particularly who it was.

Mr. FULTON. What do you think about the need of a law by Congress? Should we put this into law?

Mr. SCHMICKRATH. I am again out of my field, sir.

Mr. FULTON. You are a citizen; you are the taxpayer. So it is right in your field.

Mr. SCHMICKRATH. We would accept without any question a logical set of standards for engine noise parameters.

It doesn't make any difference to us who passes it, if it is a logical criterion upon which to base an engine design. We would like it.

Mr. FULTON. But you would like either regulations or law that would be set by the Federal Government upon a good set of standards of measurements?

Mr. SCHMICKRATH. We definitely need a set of standards of measurement; that is right, sir.

Mr. FULTON. Then you would like everybody to conform to them; wouldn't you?

Mr. SCHMICKRATH. Yes, sir.

Mr. FULTON. And you would have penalties if they didn't, in order to protect the local communities; wouldn't you?

Mr. SCHMICKRATH. I wouldn't like to accept the penalties if I can get out of it.

Mr. FULTON. You see, the question is: Should we just hold a hearing and listen to views of various people as to the effects of noise and then provide advice for the general public, first, that there is no noise; and, second, it may be a noise but it is just not the kind that you like; third, it might be the kind of reference that Mr. Jones has his head cut off and he is not complaining; or fourth, the kind of approach you take, the way you say it, that God makes more noise in thunderstorms and you don't dare complain to Him about it, so you just have to have it?

Are we to take the position that "You just have to take it," to the public. Or shall we take the position based on these hearings—that is why I am asking the question—should Congress as a result of these hearings pass a law limiting noise and sound to tolerable levels

in various circumstances under standards that are set by an independent and impartial Federal Government agency?

Mr. SCHMICKRATH. We recognize as far as the enginework is concerned that we want to, and need to, to improve the noise suppression situation. We recognize that, and we need a set of standards to shoot for to do this. We have put a great deal of effort in it.

Mr. FULTON. But would you have the public protected by regulations or law, or just leave it for every airplane manufacturer and every commercial company transporting either passengers or freight to make up their own minds as to how they are going to conduct their operations when they know the standards?

Mr. SCHMICKRATH. I don't know who should pass the law or who should make the regulations. I think the public deserves some definite consideration.

Mr. FULTON. And that there should be compulsion of some kind?

Mr. SCHMICKRATH. If the set of standards are correct; yes.

Mr. FULTON. All right. That is a very good answer.

Now, you are an engineer. In the preliminary design of these turbojet engines, is there any consideration given right at the very beginning of preliminary design on the probable sound effects?

As you know, in submarines, they have to take that as one of the principal factors when they come to design the powerplant of a submarine.

I was on active duty in the Navy for a long while and in the Reserve since. That is one of the chief factors in designing a submarine, the noise and the noise control.

Now, is that a principal factor in this turbojet preliminary engine design? I don't think that I have ever heard of it being mentioned in the preliminary designs. They don't customarily even mention it.

Mr. SCHMICKRATH. We have been working now for 7 years to try and find ways to reduce the noise. Until we found some of these ways, we couldn't make it a preliminary item in the design of the engine. Within just this year, the previous 7 years of work has started to pay off.

In June of this year, on the turbofan engine that we have in production, we released the first set of design changes which will be in production in January of 1961.

Mr. FULTON. That is the design changes themselves, rather than components placed on the engines after design?

Mr. SCHMICKRATH. No, these are design changes to the engine which have been tested, which will improve the noise picture. It was released in June of this year for this engine.

Since we have reached this state of knowledge, we definitely have made the design of the engine contingent upon noise as one of the parameters. I think this is probably the first time this has ever been done. Our future engines, either 1 year, 2, 5 years from now will reflect our research efforts on noise suppression.

Mr. FULTON. I have checked this a little bit and acquired a compressor blade and looked at it to find its shape and configuration. When I was a kid and my father took me out and said I was to make a whistle, he showed me how to make a whistle and he put a notch on a curved reed and made it hollow, so that it was in a tube, and he said if I blew on the top of that edge I would get a whistle.

And remarkably, when I saw this compressor blade, this is designed in the form of a whistle.

I would like the chairman to see it. It hasn't been properly machined.

The CHAIRMAN. Do you want to demonstrate it?

[Laughter]

Mr. FULTON. Let the witness demonstrate it. It is a whistle, you see. The configuration is designed for a whistle. And that is the thing that we heard that had the loud shriek, the high note.

Mr. SCHMICKRATH. Also the one you heard, sir, that didn't have the loud shriek has the same rubbing edges at the top of the blade as this one has.

But there are other changes in the relation of blades to each other and to vanes and spacing that change the noise characteristics and eliminates the high-pitched whistle.

Mr. FULTON. Yes. But isn't it a fact that when they make these blades they don't really machine them at the edge, they just let them wear down by putting them in the tube and then when they wear down, why, that is where they are, with no tolerance?

Mr. SCHMICKRATH. No, sir. Those blades are finished to a very definite tolerance, all compressor blades and all turbine blades are. The engine wouldn't have performance if it didn't.

Mr. FULTON. I am talking about your tolerance. I realize that they are machined to a certain degree. But then they are put in and they wear in, don't they?

Mr. SCHMICKRATH. No, sir. Not if we can help it. We don't have any parts rubbing in a jet engine if we can help it, definitely.

Mr. FULTON. But you don't design blades like that, do you?

Mr. SCHMICKRATH. Yes.

Mr. FULTON. Why do you put——

Mr. SCHMICKRATH. The notch in the top? That is actually a rubbing notch in case they do happen to touch. There are other blades where this top edge is thinner because of design problems.

Mr. FULTON. Has any design been tried to eliminate that notch, which causes the whistle, obviously?

Mr. SCHMICKRATH. That is not the item that causes the whistle, sir.

Mr. FULTON. Certainly if you look at it, you can see that that is the design of the kid's whistle.

Mr. SCHMICKRATH. But we are able to eliminate the whistle without changing that top of the blade.

Mr. FULTON. The next thing is this. I use the airports a lot and have been interested in various companies and have been in aviation work connected with the Navy procurement on a carrier. To me one of the troubles is that the jet engines are kept on so much longer than necessary on the ground.

For example, when the engines rev up on the ground, for example an F–86 revs up first, with the power control, then it goes down and revs up again with manual control, then it goes down and revs up again for a takeoff.

Why isn't the ground equipment designed so that you don't have the jet engines warming up in places where it is right out near people? And then the reverse, when you come down, why don't you have an engine cutoff and design something so that you don't taxi planes with jet engines?

You hear them around these airports, they taxi the jet engine right up to the terminal. Why don't you design new ground equipment to

handle that? That, to me, is as much a problem as your takeoff and landing. It is unnecessary jet noise.

Mr. SCHMICKRATH. We don't design the equipment that is used on the airports such as ground equipment for jet airplanes or piston airplanes.

Mr. FULTON. No; but why don't you have something that you could switch to that would assist in the taxiing under other power than jet power on the ground?

Mr. SCHMICKRATH. That could be an excellent idea. We have never looked at it, sir.

Mr. FULTON. Would you look into it? Because I am a user and that is one of my big complaints. It is unnecessary use of jet engines for purposes for which they were never designed.

Now, then, is it possible on the takeoff to use some other sort of power to get them up to a point where the jet engines could take over at an altitude where they are most efficient and you get the best specific impulse?

Mr. SCHMICKRATH. The aircraft people should answer that one. That is a function of the airplane design.

Mr. FULTON. Has any work been done in that field?

Mr. SCHMICKRATH. I don't know, sir. Not from the engine standpoint.

Mr. FULTON. Thank you. You are a very good witness. We appreciate your coming.

Mr. SCHMICKRATH. Thank you.

The CHAIRMAN. He is a good witness.

Any further questions on this side?

Mr. DADDARIO. I have just one.

The CHAIRMAN. Mr. Daddario.

Mr. DADDARIO. Mr. Schmickrath, you in the course of your statement have brought out the fact that over a period of time in the development of airplane engines we have gone through phases and apparently the public has acclimated itself to changes as time has gone on, and that during the course of all of this, apparently you people in the engine business have always kept in mind the noise factor and have tried to develop aircraft accordingly.

As you get to the turbofan engine you stress the fact that it will give you increased efficiency in takeoff and initial climb. I wonder what comparisons can we then make to performance once the airplane is in the air between turbofan and jet, maneuverability, speed, all that type of thing?

Mr. SCHMICKRATH. The normal jet engine—and I am referring to the J–57 because our fan at this stage of the game is a J–57 conversion—the normal jet engine has lower thrust for takeoff than the fan engine. In fact, it is the ratio of 13,500 pounds to 16,000 pounds thrust for takeoff.

The normal jet engine has a silencer on it, both Douglas and Boeing aircraft. This causes a loss in overall economy for the airplane of about 3 or slightly less percent.

The fan engine with its higher takeoff thrust and its lower jet velocity improves the noise of the fan-powered engine, which is a replacement for the J–57 engine in the same airplane. A noise reduction of about 10 decibels is achieved, as far as the takeoff is concerned.

The fan with the noise changes that we have released to reduce this compressor whine, have no performance loss. They get the same

thrust and same specific fuel consumption. We have been able to design it that way so we could do this. So we get the noise improvement without a loss in either thrust or specific fuel consumption.

I don't know whether I answered your question or not, sir.

Mr. DADDARIO. Does this apply if we were to compare both types of engines once they have arrived at the best altitude to fly from one point to another——

Mr. SCHMICKRATH. Yes, sir.

Mr. DADDARIO. Does the performance level still remain the same?

Mr. SCHMICKRATH. Essentially. The mach number of the airplane of course limits how fast they go. So it depends on the design of the airplane.

Mr. DADDARIO. We can gather from what you have said that the turbofan is an improvement in the course of engine construction?

Mr. SCHMICKRATH. It is a wonderful improvement, one of the best things that has happened in a long time. We are very pleased with it.

Mr. DADDARIO. Thank you.

The CHAIRMAN. I would like to ask you just one question in reference to the history of the work of Pratt & Whitney.

When did Pratt & Whitney start making airplane engines?

Mr. SCHMICKRATH. 1925.

The CHAIRMAN. And you have been in business ever since, making airplane engines?

Mr. SCHMICKRATH. Yes, sir.

The CHAIRMAN. You have had about as much experience in designing and developing engines as any like corporation?

Mr. SCHMICKRATH. We believe so.

The CHAIRMAN. Thank you very much, sir, for the testimony you have given us. It has been very, very helpful to us.

Mr. SCHMICKRATH. Thank you.

The CHAIRMAN. Now, the next witness we have this morning is General Quesada, Administrator of the Federal Aviation Agency.

General Quesada, we are very happy to have you here.

I would like to recess the committee for a couple of minutes because we have a photographer here. If the general doesn't object, we would like to have the whole committee group here in the picture with General Quesada.

(Recess taken.)

The CHAIRMAN. The committee will come to order.

General, who do you have sitting with you, so that the reporter may get the names and their titles?

General QUESADA. I have on my right, Mr. Daggett Howard, who is the legal counsel for the Agency. And I have on my left, Gen. Paul Preuss, who is the Assistant Administrator for Plans.

The CHAIRMAN. General, I might say by way of introduction that I have known you for many years and admired your fine work in the military. I have also had the privilege and pleasure of working with you in the advancement of the Reserve program where you did a signal and outstanding job for the Reserves.

Now you head a new Agency and you have new and difficult, and, I might even say, baffling problems to solve.

The committee therefore welcomes you this morning. We note that you have a prepared statement. Will you please proceed. The committee would welcome anything you say.

STATEMENT OF GEN. ELWOOD R. QUESADA,[9] ADMINISTRATOR, FEDERAL AVIATION AGENCY; ACCOMPANIED BY DAGGETT H. HOWARD, GENERAL COUNSEL, AND BRIG. GEN. PAUL PREUSS, ASSISTANT ADMINISTRATOR FOR PLANS

General QUESADA. You are kind to me, Mr. Brooks, as always. This makes it a pleasure to come before your committee, not only because you understand the problems that we are confronted with, but you have a sympathetic understanding of them. You recognize clearly that none of these problems are easily coped with and that there are varying influences and pressures brought to bear.

With your consent I would like to put my prepared statement into the record without reading it, and give a condensed statement which might save the committee time.

The CHAIRMAN. If there is no objection, the general's statement will be placed in the record as it is.

(The prepared statement of General Quesada is as follows:)

Mr. Chairman and members of the committee, we want to thank you for inviting the Federal Aviation Agency to appear before you today on the matter of research and development in connection with the aircraft noise problem.

You have asked our Agency to direct its attention to the following two points:

(1) How big is the noise problem now, and in the future; and

(2) What research and development work is underway, and what further efforts are necessary?

Accordingly, our statement has been prepared in an effort to be of assistance to you in these two areas:

HOW BIG IS THE NOISE PROBLEM NOW, AND IN THE FUTURE

It is important to remember that in most instances airports were originally located in sparsely populated areas. Less than 20 years ago an airport was seldom found within the bounds of an established community. Most were out in the open country, where homes or other buildings were few and far between.

Today, many of these same airports are surrounded by schools, shopping centers, and housing developments.

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[9] E. R. (Pete) Quesada was appointed by the President of the United States as Administrator of the Federal Aviation Agency on November 5, 1958. He became the first Administrator of the new more powerful and comprehensive aviation agency. The FAA is an independent agency reporting directly to the President. At the time of his appointment Mr. Quesada was Aviation Adviser to the President, Chairman of the Air Coordinating Committee and Chairman of the Airways Modernization Board. As Administrator of the FAA, Mr. Quesada will be responsible for modernizing the Federal airways system, directing air traffic control of civil and military aircraft, controlling the allocation of the diminishing airspace and both issuing and enforcing air safety rules.

Mr. Quesada was born in Washington, D.C., on April 13, 1904. He attended District of Columbia grade and high schools, the University of Maryland and Georgetown University.

In 1924. Quesada enlisted in the Army and in the ensuing years rose from private to second lieutenant to three-star general.

Early in his flying career (1928) Mr. Quesada took an active part in the dramatic rescue of the crew of the *Bremen*, a German aircraft forced down off the coast of Labrador after completing the first successful east-west crossing of the Atlantic by air. He was also on board the famed *Question Mark* when it remained aloft the entire first week of January 1929, establishing a world's record for endurance and proving the efficacy of aerial refueling. During the period in 1933–34 when the Army flew the airmail, Mr. Quesada was chief pilot on the New York-Cleveland route, personally flying the round trip on alternate nights.

During World War II, Mr. Quesada served as commanding general of the 12th Fighter Command and deputy commander of the Northwest African Coastal Air Force. As commanding general of the 9th Fighter Command, he directed the American air effort prior to and during the invasion of Normandy, and directed a tactical operation in conjunction with the Army during the Allied sweep across Europe. He participated in more than 90 combat missions.

From 1949–51 he was in command of Joint Task Force 3, representing the Army, Navy, Air Force, and Atomic Energy Commission, which organized and carried out Operation Greenhouse, a series of tests which included the detonation of the world's first thermonuclear device.

Mr. Quesada holds the Distinguished Service Medal with Oak Leaf Cluster, Distinguished Flying Cross, Legion of Merit, Air Medal with two Silver Oak Leaf Clusters, and Purple Heart. His foreign awards include the British Order of the Bath, Commander of the British Empire, French Legion of Honor, French Croix de Guerre with Palm, Luxembourg Croix de Guerre, Order of Adolph of Nassau, Belgium Order of the Couronne with Aviation Palm, and Belgium Croix de Guerre with Aviation Palm.

Mr. Quesada retired from the Air Force in 1951 with the rank of lieutenant general and became associated with private industry, as a director and officer of Olin Industries and the Lockheed Aircraft Corp.

Mr. Quesada is married to the former Kate Davis Pulitzer Putnam of St. Louis, Mo. They live with their children, two daughters and two sons, in Washington, D.C.

There may be some question as to how much noisier the airport itself is than it was 20 years ago, but there is no question that the noise is being heard better by its new next-door neighbors.

There undoubtedly has been some increase in the noise level of the airport as our air transportation system expanded from a slow start in the late twenties and early thirties, as larger and more transports were developed and as the increase in business and private flying continued.

Piston-engine-type aircraft became commonplace—their sight, their sound, their use. Against this background of familiarity with and use of aircraft, came new and different sounds: the high-pitched whine and the roar of the turboprop and the jets.

The public first became aware of these unusual sounds after World War II when our military jets were located at bases throughout the country. The airport neighbors heard them, came to understand them, and accepted them as an essential part of our airpower. Today, as commercial jets are coming into service more and more, people are becoming familiar with the sounds of jet-age living.

Actually, jets are not significantly louder than reciprocating engines. But, because of the extraordinary difference in the pitch of the two, the human reaction to their sounds of equal loudness is not the same.

High frequency sound has a different impact on the human ear than does low frequency sound, and many persons who barely notice piston-engine noise are immediately aware of the higher frequency jet noise of the same intensity.

Although engineers have developed elaborate devices to measure precisely the varying degrees of noise, human beings are much too complex to be metered. Each of us may have a different "annoyance threshold," and a noise which may be very irritating to one person may be disregarded by another.

Acoustical engineers point out that such things as the frequency of sound make a difference to a person on the gound even when, according to measuring devices, the sounds are of equal intensity.

The Federal Aviation Agency has recognized that objectionable noise emanating from aircraft operating into and out of some airports has reached a level of seriousness that warrants the development of specialized research studies, operational techniques, and procedures designed to alleviate noise levels and promote effective airport and community relations. We consider that the noise problem, next to safety, is the most critical one we face.

The Federal Aviation Agency, the airport and engine manufacturers, airlines, airport operators, and pilots are aware of the disturbance that aircraft noise may cause the people living in proximity to airports.

The aviation industry, deeply aware of its responsibilities in this matter, has formed an independent organization known as the National Aircraft Noise Abatement Council to coordinate a nationwide, industrywide program to explore every possible approach which might help reduce noise due to aircraft operations in airport terminal areas.

NANAC's three founding members include the Air Transport Association, representing the airlines, the Aerospace Industries Association, representing the manufacturers, and the Air Line Pilots Association.

The members have pledged themselves to apply every reasonable and safe flight operations procedure and technique developed by NANAC, and to follow every avenue of research into noise reduction methods and devices suggested by the council in the hope of realizing an acceptable solution to this difficult and complex problem.

Ground noise has been reduced by using jet-silencing screens and ground jet-noise suppressors at maintenance and overhaul bases where prolonged engine tests are necessary as a routine safety matter. Portable mufflers, blast fences, and other devices can also be used to deaden the sound. However, at present there is no satisfactory answer to the noise created by engine runup just prior to takeoff.

While flight noise cannot be as easily and effectively handled as some of the ground noise, certain things can and are being done in this field to provide a measure of relief.

For example, the intensity of sound decreases as distance from the sound source increases. Applying this fact to aviation sounds, the FAA is requiring as much distance as air traffic safety will permit between aircraft taking off and landing and the persons within the hearing range of the engines. This is being accomplished by issuing new rules for the control of air traffic, establishing a system of preferential runways, changing operating techniques.

Traffic rules.—Local airport traffic rules are being changed by rearranging the air traffic patterns. This is an exceedingly complex procedure which, in essence,

means alining approach and departure courses whenever possible over water, uninhabited, or thinly populated areas.

Preferential runways.—The preferential runway system assures that the control tower, when it is safe to do so, concentrates incoming and outgoing traffic on runways which offer the least possible sound annoyance to the most people.

There are circumstances, however, when comfort must give way to safety, which must be the paramount consideration of every FAA action and rule.

For example, when a crosswind landing might be dangerous, runways other than the preferentials must be used. When visibility is low, incoming aircraft must be brought in on the instrument runways and they are not always in the best positions from a noise standpoint.

Operating techniques.—As a part of the Federal Aviation Agency's contribution to noise abatement, standard operating procedures for jet aircraft have been developed. These suggestions have been published and I am pleased to say they result from cooperation between our Agency and many aviation interests. These procedures are a direct result of cooperation that I requested from the aviation industry.

It is appropriate here to cite the letter that I wrote to airline presidents asking for their cooperation on this matter last February.

"I am sure you share my deep concern over the problem of aircraft noise, a problem which has become increasingly acute with the introduction of the jet transport. The future of our air commerce may very well rest on the success of our mutual efforts.

"At airports located in some of the larger metropolitan areas, many constructive and fruitful steps have already been taken by the cooperative efforts of industry, airport authorities, and this Agency, in sincere and straightforward attempts to make air transportation an acceptable industrial neighbor in the community. There is no need for me to review the history of these actions at this time. It is apparent, however, that the steps taken to date in our noise-abatement efforts have achieved less than the maximum desired effectiveness. The increasing public concern in noise-sensitive areas may well result in the imposition of drastic restrictions on aircraft operations which might deal a crippling blow to the progress of the air transportation industry. This fact, coupled with the imminence of the open-window season, makes it imperative that we act without further delay to insure that all possible steps are being taken to minimize the noise levels inflicted upon our airport communities.

"I feel it imperative that we establish a national program with effective standards and procedures, particularly in the area of optimum takeoff-and-climb and approach-and-landing procedures, not only for the current turbine-powered transports but also for piston-powered aircraft. These procedures must have as their objectives the lowest possible noise levels consistent with maximum safety. In this connection certain operating procedures were developed by the Air Transport Association, industry, and the Civil Aeronautics Administration during 1952–53; these should be reviewed and updated where necessary. It is imperative that these procedures be incorporated in your training program, and we shall have to depend on you heavily for strict compliance with these procedures in the interest of noise abatement.

"In view of the extremely urgent situation which faces all of us, I believe it desirable to form a special working group to develop the standards and procedures, on which there will be representatives from the operators, manufacturers, pilots, and the Federal Aviation Agency. In the interest of simplification I shall contact the Air Transport Association, International Air Transport Association, Supplemental Air Carrier Conference, Independent Airlines Association, Conference of Local Airlines, Air Line Pilots Association, and the Association of Local Transport Airlines with respect to the details of establishing this group.

"I must also call your attention to another critical area—the ground runup problem. This has been a source of strenuous and widespread complaint, particularly when it occurs during the normal hours of sleep. I shall have to look to the carriers for effective control measures, and I would urge immediate consideration of procedures and hardware to alleviate this serious problem.

"Whereas the FAA has the responsibility under the act to provide 'for the protection of persons and property on the ground,' there is a practical limitation in that we can only deal with the noise problem through the promulgation of air traffic rules. Accordingly, a large share of the responsibility in the noise abatement area must rest upon the operators themselves through strict compliance with optimum operating techniques and effective control of maintenance procedures involving engine runup.

"There is one further point which may well merit consideration. I find a consistent theme running through many of the complaint letters to the effect that the noise nuisance is inflicted on the community for the benefit of the relatively few who enjoy the benefits of air transportation. Perhaps an institutionalized campaign as to the contributions of air transportation to the American way of life might serve to counteract this thinking on the part of the airport neighbors. Surely these same people would not recommend curtailment of the railroads simply because they never ride them, for they are well aware that the railroads are essential to the welfare of the Nation. This is a thought that perhaps could be further developed by the working group.

"Your prompt personal attention and active cooperation in this major problem is considered essential to the successful accomplishment of our objective. May I have the benefit of your thoughts in this grave matter, with specific reference to the proposals mentioned above. Recommendations as to the composition of the working group would also be welcome."

An additional step that has been taken to reduce aircraft noise relates to flight training activities. Airlines have been requested to use airports that are less sensitive to noise for flight training activities.

Cooperation on this score has resulted, in some instances, in a decline in the total number of flight operations in noise-sensitive areas. This action is especially significant when it is realized that the air carrier operating costs are generally increased when this is done.

Our experience has shown quite clearly that many times noise problems are aggravated by a lack of understanding of how aircraft operate. Many people understandably become alarmed when they see and hear aircraft land or take off if they are not familiar with the techniques and procedures involved.

Any time fear is generated, resentment and stress usually follow. Thus it is that we are doing everything possible to work with local, State, and other groups to help educate the general public about basic fundamentals of aviation that, once understood, will help remove some of the fear.

Actually, the most direct and effective solution to the problem of aircraft noise reduction is to deal with it at its source.

Contrary to common impressions, the primary cause of noise in conventional aircraft is the propellers, not the engine. In jet engines, noise results when a powerful blast of high velocity gases come in contact with the outside air. Thus the actual noise takes place at a point to the rear of the aircraft engines.

Despite the fact that dealing with the problem of muffling or suppressing engine sounds at their source is an almost insurmountable problem, large sums of money are being expended to this end by every interested group, both in industry and in government.

One result of this effort is that all civil jet transports are equipped with noise suppressor devices which are effective to a degree.

The basic problem is that limiting the noise of an engine at its source also limits the power available to fly the aircraft. Thus it is that the scientific search goes on for a method of reducing the noise without jeopardizing the source of power.

Quite frankly, with present equipment, complete noise abatement at the source of power is impossible. On the positive side, a new type engine known as the turbofan, while not necessarily quieter, develops greater engine power and will enable an aircraft to climb out of hearing range more rapidly than some of the present aircraft.

One problem that is sometimes overlooked stems from the fact that no Federal agency has the power to zone property in the vicinity of airports. This is the province of the local community.

Thus, while it may appear as hindsight, it must be pointed out that responsible community leaders must act with courage and foresight in establishing zoning criteria that will preclude residential and similar noise-sensitive developments springing up adjacent to an airport.

Unless this is done, homes and schools will continue to be built too close to existing airport approaches. This is the approach being used in planning for the Dulles International Airport which we hope will serve as a guide to other communities.

Accordingly, as to how big the aircraft noise problem is and to what to expect in the near future, it can be said that this problem is serious today and that with scheduled increases in jet operations at more and more airports it will become even greater. We also see the continual crowding in toward the airports of residential developments, which developments contribute additional complaints from the airport neighbors.

WHAT RESEARCH AND DEVELOPMENT WORK IS UNDERWAY, AND WHAT FURTHER EFFORTS ARE NECESSARY?

The second part of our statement, dealing more specifically with the area of research and development, has been prepared under three headings, namely, "State of the Art," "Research on 'Noise at the Source,'" and "Ancillary Noise Reduction Research."

STATE OF THE ART

As the first phase of the research program on aircraft noise, research and development is being conducted through studies of the aircraft noise problem, and by evaluation of efforts going on in industry.

Attention is being given to what is being done and planned to alleviate the noise problem, such as the state of the art in engine and suppressor design.

We are also evaluating the efforts being made to alleviate the noise problem at the public relations level, and the efforts of noise measurement.

The goal of this initial effort is to pull together all of the research and experience on the noise problem. The basis is being laid for recommendations as to immediate action where such action would contribute to the alleviation of the noise problem, with the idea of guiding further research and development work into the most productive channels, and avoiding duplicate efforts with other Government agencies and industry.

A preliminary memorandum report on "Sound Barriers and Turbojet Engine Runup" has already been received from Cornell Aeronautical Laboratory. This proposal is to investigate the sound-attenuating properties of batteries of water sprays, which work both by acting as a solid carrier would, and by cooling the hot, turbulent gases. The final report on the whole initial program is due later in August.

RESEARCH ON "NOISE AT THE SOURCE"

Data is being compiled on possible ways to suppress noise at the source, and surveillance is being maintained on development of noise suppressors and quieter engines in the industry.

An example of work being done in industry is the aft-fan jet engine developed by General Electric. We understand that General Electric is submitting a description of this engine to your committee.

This engine, which is now fully developed, will be at least 9 perceived noise decibels (9 PNdb) quieter on takeoff than regular suppressed jet engines now in use. On approach, this aft-fan jet engine is not, in its present form, much less noisy than conventional jet engines, due to the whine from the bypass fan.

However, General Electric is developing an advanced version of this engine in which the fan whine will be suppressed to an important degree.

Other powerplant manufacturers are making similar progress in developing quieter engines. Our policy in regard to supporting research and development is that we are prepared to support work which has Agency approval by encouraging private industry, and secondly, when necessary and within Agency responsibility, by funding programs.

ANCILLARY NOISE REDUCTION RESEARCH

A concerted effort is being made to investigate the ancillary problem of ground aircraft noise. The costs and effectiveness of both fixed and portable barriers against noise generated by aircraft on the ground are being computed.

It would appear that barriers are not a cheap cure-all for ground noise, but they would definitely be a reasonable solution in certain particular situations.

An example of sound barrier research is the proposal of the spray barrier made by Cornell Aeronautical Laboratories which was mentioned above.

The spray barrier has the particular advantage that it would be "erected" only when a plane was about to take off and thus would not be in the way of a landing aircraft. Such a barrier might be a reasonable solution to the noise problem at San Francisco International Airport, where the neighborhood town of Millbrae exists only a few hundred feet from the end of a runway, and is subjected to intolerable noise, direct exhaust, and soot, when jet aircraft use that runway for takeoff.

There are other circumstances where barriers might be feasible. For example, a new runway at Los Angeles International Airport runs parallel to and only about 1,000 feet from a high-cost residential area.

According to our calculations, a wall or earthen dike 20 feet high would afford very substantial relief to the adjoining residential area. Experimental sound barriers will be evaluated at NAFEC if such evaluation is necessary.

The Federal Aviation Agency has tentatively selected for adoption as the U.S. standard the British RAE visual glidepath indicator which provides information to pilots on the correct angle of descent.

While this device is primarily directed toward safety, it does make some contribution to noise abatement by providing guides to pilots, which enables them to remain at or above the glidepath angle on approach.

This indicator will enable the pilot to maintain better control of his glidepath on landing and thus assure that his landing path is over a controlled course at prescribed heights, confining the noise to a defined area.

In conclusion, while noise abatement is a serious national problem today, and will continue to be a serious problem in the future unless some spectacular breakthrough in noise suppression at the source is achieved, we feel that we are making reasonable progress within the limitations of existing technology and through the courses of action which I have outlined.

Increased jet operations in critical areas and the establishment of this service at more airports will amplify the problem to some degree. In all candor, the future outlook has both bleak and promising aspects.

There are no immediate and dramatic means of completely stifling the sounds that accompany essential air transportation. Despite this, increasingly effective methods of reducing and tolerating noise are being developed and put into effect.

With advanced planning and the concerted effort and cooperation of the industry, the airport operators and the affected communities, we believe that the noise nuisance can be held to an acceptable level commensurate with progress in air transportation.

General QUESADA. We want to thank you for inviting the Federal Aviation Agency to appear before you today on the matter of research and development in connection with the aircraft noise problem.

We have suggested that our statement be prepared and filed for the record, which has been done, and that we offer you at this time a summary of that statement.

There has been an increase in the noise level of the airport as our air transportation system has expanded. As commercial jets are coming into service more and more, people are becoming familiar with the noise of jet-age living.

While jets are not significantly louder than reciprocating engines, the human reaction to their sounds of equal loudness vary because of the extraordinary differences in pitch of the high-frequency jet noise when compared with the low-frequency sound of the reciprocating engine.

The Federal Aviation Agency has recognized that the aircraft noise problem has reached a level of seriousness that warrants specialized research, and the development of techniques and procedures to alleviate noise levels.

The aviation industry has recognized its responsibilities in this matter and has formed an independent organization referred to as the National Aircraft Noise Abatement Council, and commonly known as NANAC. The members of this organization have pledged themselves to follow every avenue of research into noise reduction methods and devices.

The intensity of sound decreases as distance from the sound source increases. Applying this fact to aviation sounds, the Federal Aviation Agency is requiring as much distance as air traffic safety will permit between aircraft takeoff and landing and the persons within hearing range by (1) issuing new rules for the control of air traffic, (2) establishing a system of preferential runways, and (3) changing operating techniques.

Zoning criteria to preclude residential and similar noise-sensitive developments from springing up adjacent to Dulles International Airport is planned with local communities and it is hoped that this approach will serve as a guide to other communities.

I would like to interject here that the committee might like to inquire into what they are.

In the area of research and development, studies of the aircraft noise problem are being evaluated. For instance, General Electric is doing work on the aft-fan jet engine which is much quieter on takeoff than regular suppressed jet engines now in use, and other plane manufacturers are making similar progress in developing quieter engines.

Another proposal being evaluated is a water spray barrier proposal which has been made by Cornell Aeronautical Laboratories. This involves the erection of a spray barrier when a plane is about to take off and thus would not be in the way of landing aircraft.

We have concluded that noise abatement is a national problem today, and will continue to be a problem unless some spectacular breakthrough in noise suppression at the source is achieved. The outlook is both bleak and promising.

There are no immediate and dramatic means of completely stifling the sounds that accompany essential air transportation.

However, with advanced planning and the concerted effort and cooperation of the industry, the airport operators, and the affected communities, we believe that the noise nuisance can be held to an acceptable level commensurate with progress in air transportation.

That is substantially, sir, what the longer statement said, and I would be more than happy to have any questions.

The CHAIRMAN. Thank you very much, General.

I have glanced over your longer statement, of which your oral statement forms a part, and I would like to ask you a few questions.

How does the FAA interpret its position relative to the noise problem which has become so acute in turbine engines?

General QUESADA. Prior to the creation of the Federal Aviation Agency, Congress had not vested authority in any Government agency to control aircraft noise. The authority, in fact, does not exist. And this has been alluded to in previous testimony.

In enacting the Federal Aviation Act of 1958, the Congress authorized and directed the Administrator of the Federal Aviation Agency to prescribe rules and regulations governing the flight of aircraft for, among other purposes, the protection of persons and property on the ground.

While the legislative history of this provision contains no express recital that noise abatement was a reason for this provision, we nevertheless believe that the language of this section to authorize noise-abatement regulation is in this area.

Thus, in the area of issuance of air traffic rules the Federal Aviation Agency may undertake action toward noise abatement. This does note negate nor lessen the responsibility of other parties, that other parties may have to provide relief from offending aircraft noise.

Aircraft manufacturers, pilots, airlines, airport operators, and local government authorities have a complementary responsibility in various areas of this mutual problem.

We have organized within the Office of the Assistant Administrator for Plans, a branch especially responsible for the monitoring aircraft

noise studies and activities undertaken by the various offices and bureaus of the Agency.

Such office is to further the focal point of FAA contacts with noise-abatement activities outside of the Agency. We are studying the noise problem at particular airports and have already issued an air traffic rule designed primarily for noise abatement that is now effective in Los Angeles.

We have issued similar proposed rules for Washington National Airport and the New York International Airport. The rule for the latter will be issued soon.

The final rule for the latter airport is expected. We are further currently planning to issue a proposed air traffic control noise-abatement rule of national application with provision for local modification to fit the needs of air traffic control at a particular airport.

These rules restrict the use of delineated airspace and runways and prescribe minimum altitudes and air traffic patterns to govern takeoffs and landings.

We are doing our best in this area to balance the equities. I would be misleading the committee if I left the impression that we were solving the problem. Our effort so far is designed to bring relief to the problem, to the extent that we are able under the terms of the law and are able within the limits of our own imagination, and we have to give consideration in all cases to a necessary high standard of safety.

The CHAIRMAN. General, do you have close liaison with NASA in reference to this problem?

General QUESADA. Yes; we do. We work very closely with NASA.

The CHAIRMAN. Do you have a committee setup, or how is your liaison established?

General QUESADA. It is established through General Preuss, and there are noise committees that we are a part of. The NASA is a very, very active, willing, and constructive party to our efforts to abate noise. Their technical competence is as highly developed as any in the world, and certainly is equal, if not better, than any in this country.

They have spent a great deal of effort, money, and time in developing devices and means of reducing the amount of energy that goes into noise and abating noise. They are very effective.

The CHAIRMAN. Is it possible in your judgment by reducing the energy that goes into noise, to actually increase the power of the engine in the plane, or is that wasted energy?

General QUESADA. Well, it is wasted in terms of useful power, but it is not wasted in terms of the result. If it does—if, say, 2 percent of the energy that an engine is capable of developing goes into noise suppression, as far as we are concerned we don't consider it wasted.

Of course, the aircraft manufacturer or airport operator might. But I don't think they do. I think you have seen a dramatic demonstration of the advances of technology when you heard described the turbofan that is about to come into useful service.

For your purposes, the same engine with approximately the same weight will develop approximately 25 percent more thrust and at the same time not produce more noise.

Now, this is accompanied by an added problem. It will be the natural inclination of the aircraft operator to turn this technological

development into increased payload or deprive the citizenry of the benefits that this development brings.

They could, as an example, just take the fuselage, cut it in half and put a little filter in there and make it longer, which they have done in the past, and have an airplane that could carry more passengers. And it would have—although it has more thrust, it would substantially have the same performance as the airplane that we now have.

I am hopeful that the airlines and the aircraft manufacturers will turn this technological development of added thrust without added weight into noise-abatement problems, which would permit the airplane to get out of the airport faster, or climb faster, which would definitely bring a substantial relief to the public.

The CHAIRMAN. Would the elimination of noise tend to produce more power in the engine?

General QUESADA. I don't quite understand the question, Mr. Brooks. I would like to say, however, that about 90 percent of the problem that comes to our attention, about 90 percent of the public inconvenience because of this noise is derived in the threshold of landing, and in the area immediately after takeoff.

These are the critical areas, the last couple of minutes or 5 minutes before landing, and the first 5 minutes after takeoff.

Now, I don't quite——

The CHAIRMAN. Does noise from the engine exhaust represent wasted energy? Is it due to turbulence of the atmosphere that consumes some of the energy or power of the engine in the plane?

General QUESADA. I don't think that there are any suppressors that are especially added to the engine for that particular purpose that don't consume some of the energy.

I can't think of any device that is designed specifically for noise suppression that doesn't have these two factors: It automatically adds weight, and I don't know of any that doesn't consume some energy to suppress the noise.

But there are developments that increase the thrust by substantial amounts, such as the turbofan. It increases the thrust by, say, 25 percent. It might increase the weight by 5 percent and it doesn't increase the noise by any percent. So therefore this is——

The CHAIRMAN. Let me ask you another question.

Do you maintain close relationship with the manufacturers of airframes and engines?

General QUESADA. I might have the person who does it, in addition to myself, General Preuss, answer the question.

General PREUSS. Yes, sir; we do. We have had very fine relationships with both Pratt & Whitney and General Electric.

The CHAIRMAN. They feel free to make suggestions to you in reference to noise elimination?

General PREUSS. Yes, sir. We have most open kinds of discussions.

The CHAIRMAN. You feel free to make suggestions to them?

General PREUSS. Yes, sir.

The CHAIRMAN. So your relationship is good between the manufacturer and yourself?

General PREUSS. Yes, sir. And we are impressed with the attitude and the efforts they have been taking in this area.

The CHAIRMAN. Do you anticipate a greater problem from noise in the operation of supersonic air transports, especially in reference to the sonic boom?

General QUESADA. I will start, and he might finish. There are two basic problems here, Mr. Brooks. That is, the noise that the supersonic airplane—noise nuisance that the supersonic airplane would create in the immediate vicinity of airports.

This is substantially the same problem that we have discussed so far, and should be separated in our minds from the sonic boom, because there are two different types of things—two different things, I should say.

The supersonic transport, as far as we are able to foresee the problems, is not going to increase in a substantial way the noise problem in the immediate vicinity of the airport during the landing or takeoff.

I think the committee would like me to explain why I say this. The airplane is obviously going to be heavier than those that we have today. It is obviously going to be larger than those we have today.

In order to accelerate through mach 1 and sustain a high mach number, say of 2, 3, or 4, requires a great deal of energy or thrust.

Now, you must remember that that same thrust is available for takeoff. So, therefore, you will have a lot of thrust for takeoff and a lot of thrust for very fast climb.

So the necessity for a great deal of thrust in the airplane helps this out. It alleviates our problem by permitting this airplane to climb very, very fast immediately after takeoff.

The CHAIRMAN. Now, a corollary of that, if you had a vertical takeoff, wouldn't that help, too?

General QUESADA. That would help, also.

The CHAIRMAN. Are there any prospects for that sort of change?

General QUESADA. There are prospects. They are the gleam in the eye of many. Many people are working on it.

I feel that eventually it will come, but I don't anticipate a vertical rising transport that is capable of either transsonic or high subsonic or supersonic speeds and long range coming within the area of concern to us now, within the period of time of concern to us now.

I think we are talking of 10, 15, and 20 years in the future, if you don't mind me speculating on this.

The CHAIRMAN. Thank you, General.

Any questions?

Mr. Bass.

Mr. BASS. General, you said earlier that 90 percent of this noise problem concerns landing and taking off in the vicinity of an airfield.

In my area, where I come from, where we have no airfield nearby, 90 percent of our problem is from sonic booms. Hardly a day goes by that the inhabitants of southwestern New Hampshire don't experience two or three sonic booms of varying intensity.

Has the FAA made any study of this phenomena?

General QUESADA. Yes; we are, and I think it might be better if General Preuss went into the details.

Mr. BASS. General, I would appreciate it if you would tell the committee what the FAA has done in this field.

General PREUSS. Actually, we have had very great help from NASA and the Air Force.

As late as last week the Air Force and NASA, also with the cooperation of the Atomic Energy Commission, in providing certain instrumentation, had a field experiment, quite extensive, out in the Las Vegas Gunnery and Bombing Range, Indian Springs Air Force Base.

You may recall that part of the country that is desolate and where the Atomic Energy Commission used to test atomic weapons.

Many types of aircraft were flown over the arrays on the ground, pressure pickups on the ground. High performance fighters as well as—we had 17 passes of the B–58 at various altitudes.

Now, our information is all in tapes now and will be read out and analyzed, so we have no conclusions that we can draw at this moment.

General QUESADA. I think it is worth adding here that we must differentiate between the noise created by jet airplanes and the sonic boom. Technically, they are two different things. You could say that a sonic boom is not noise, it is a change of pressure.

Now, to get more specifically to the point, however, the Air Force is aware of the annoyance that comes to the public from sonic booms. They are very anxious, obviously, to reduce this annoyance on the one hand, and still be able to function, on the other.

The Air Force and the Navy have to fly, and sonic booms are going to accompany their flight at an increasing rate. I think we must admit this.

The Air Force is doing, I think, what it can to reduce the penalties of sonic booms. They are requiring the transition to supersonic speeds to occur at higher altitudes where the effect would be less. They are requiring this transition to occur in areas in which they feel that the effect would be less.

We are trying to develop some data on what creates a sonic boom, because there is a vacuum of information in this area. I must tell you very frankly. We don't know precisely the conditions or all the conditions under which a sonic boom is created. Nor do we know the conditions that create varying intensities of sonic booms. And this is the purpose of the program that General Preuss alluded to.

It is a serious problem. I am afraid that it is one of the penalties of progress that we must, to a reasonable degree, accept and accommodate ourselves to, and, at the same time, we must do everything we can to reduce and eliminate the annoyances to which you justly refer.

Mr. BASS. General, you will be interested to know that the people in my area, after they are advised of the inevitability of this phenomenon, understand that this is necessary if we are to maintain an adequate defense posture, and so forth. Where it becomes serious, however, is when property damage occurs, which has happened from time to time, and in every case, every claim, to my knowledge, has been turned down by the Air Force.

Referring back to the FAA study, as I understand it, you have in conjunction with the Air Force made some extensive experiments in this field, but you are not prepared at this time to tell us what the results are.

General PREUSS. That is correct.

Mr. BASS. Or to give us any conclusions.

General QUESADA. Well, I just might say I hope you won't be offended by the manner in which I say it: We have more ignorance than knowledge in this area at the moment. It is a very, very difficult

problem. We are accumulating information on it. It is a new problem.

I think the aviation community to some extent is surprised by the problem and the information that we are accumulating has to be digested and turned into useful information.

I hope you don't mind me being very frank about it, but these are the facts.

Mr. BASS. I appreciate your frankness, General, because it is helpful to me in explaining to people that are startled or annoyed, or sometimes outright terrified when they hear this tremendous noise that occurs, it sounds just like an explosion.

General QUESADA. It does. I will tell you very frankly, I have been frightened by it. It comes without warning.

I think one of the things we can do now is to reduce it to the absolute minimum, compatible with necessity. I think we have got to balance the equities between these two ends of the problem.

Mr. BASS. Does the FAA exercise any jurisdiction or control over the Air Force in supersonic flights of Air Force planes over inhabited areas?

General QUESADA. This is a little bit hard to think out.

We are responsible for the management of all air traffic, whether it is military or civil.

When the Air Force is operating outside of so-called restricted areas, our exercise of control on those occasions, when it is to their interest to fly at supersonic speeds, our control is not that you can't fly at supersonic speed, our control is exercised: you can't fly at supersonic speed if it creates a hazard to other traffic.

So we don't preclude them from flying at supersonic speed, we only preclude them when it would bring a public hazard to other traffic.

Mr. BASS. Don't you also have a responsibility over hazards to people on the ground and to property on the ground as well, due to sonic boom?

General QUESADA. This is a legal problem, and I thought it might be well for Mr. Howard—you would be better informed if the legal counsel answered it.

Mr. HOWARD. Mr. Bass, I might comment briefly on the legal authority that the Agency has in this area. We do have authority to issue air traffic rules which are designed for the protection of persons and property.

The CHAIRMAN. Can you talk just a little bit louder? We are having trouble hearing.

Mr. HOWARD. We do have authority to prescribe aid traffic rules for the protection of persons and property on the ground.

The question that you asked as to whether we could legally determine, we will say, the altitude or location at which a sonic boom might be created by a military aircraft, I think I would have to answer in the affirmative.

We haven't done this yet. It is, however, I think, consistent with the power that we have.

Mr. BASS. The present policy of the Air Force now, so I am informed, is to allow supersonic flights over inhabited areas at 30,000 feet or more.

The Air Force has concluded, at least based on present information, that no damage can result, no property damage can result if a plane is flying at 30,000 feet or more at supersonic speeds.

Now, does the FAA intend to make an independent investigation of this to determine whether or not that is right? Are you interested in this area?

General QUESADA. The measurements and the test program to which General Preuss addressed himself, Mr. Bass, is going to give us—we hope—some useful data that would tell us just what the effect is of a sonic boom which has originated at varying altitudes, or to put it in more technical terms: we hope to get some data that will let us know exactly what overpressure that is generated from a sonic boom is. Whether it originates at 20,000, 30,000, 5,000, and then you can translate that into whether it is reasonable to suppose that property damage could result.

This is the technique that has been employed rather successfully and which I have personally had a part in, in our atomic energy programs, because the Atomic Energy Commission and the services are vitally interested in effects, and one of the varying effects of nuclear explosions are from overpressure.

So there is a similarity between the two, remote though it may be.

Mr. BASS. Then, General, as I understand you in relation to my last questions, the FAA does have a very definite interest and responsibility in this field with regard to the protection of life and property on the ground?

General QUESADA. We do.

Mr. BASS. Due to sonic booms?

General QUESADA. And other hazards created by aircraft, including sonic booms.

Mr. BASS. So that in the future, as you find out more information about sonic booms, I assume that the FAA will be working closely with the Air Force in developing rules and regulations to protect people and property?

General QUESADA. Yes, sir; we will.

And the Air Force is contributing supersonic airplanes, the B–58, to be specific——

The CHAIRMAN. Will the gentleman yield?

I should like to make one point. In case of crowded areas, the FAA has authority, does it not, to establish the rules covering all airplanes, military and civilian?

General QUESADA. That is correct.

The CHAIRMAN. Thank you.

General QUESADA. We would be very reluctant to permit the Air Force to engage in supersonic flight in the immediate vicinity of, we will say, the airport at Chicago, at altitudes in which there is an abundance of traffic.

This, to some extent, is because of our limited ability to control traffic when part of it is supersonic and part of it is subsonic. We must overcome this and we are trying to.

I will assure the committee that problems such as this have arisen and we have responded.

Mr. BASS. Thank you very much, General. This has been very helpful.

The CHAIRMAN. Mr. Sisk?

Mr. SISK. General, I was interested to know to what degree your Agency controls flight patterns of traffic around airports.

I realize, of course, you have very specific safety regulations and so on. But to what extent does your Agency specifically determine flight patterns?

I am referring to those patterns as they have to do with flying the pattern within the area of an airport in landing and takeoff.

Do you specify precise patterns, or generally lay out and determine the time and the altitude and the area in which left turns and right turns take place? In other words, to what extent do you govern and control the traffic from these airports so far as population is concerned?

General QUESADA. Sir, we control that with little or no reservation. We in fact prescribe, print, and publish and monitor the traffic patterns around airports wherein the volume of traffic is such that a traffic pattern is essential to orderly movement.

We wouldn't prescribe a traffic pattern around a small field in Monroe, Mich., where I used to live, that has, say, three airplanes.

On the other end, we prescribe with considerable definition the traffic patterns around the two airports in Chicago, if I may use that term again, without any—I seem to be picking on Chicago. I don't mean to be.

Mr. SISK. I would like for you to pick on Washington once in a while. [Laughter.] The point I have in mind, and I think the thing we are concerned with, is the nuisance of noise as it affects our population, as it affects damage that may occur to property, but particularly as it affects human beings.

I am not being critical, General.

General QUESADA. I understand that, sir.

Mr. SISK. Because I realize safety and safety regulations must be predominant, because I fly a lot and I want you to be sure that is uppermost all the time, in spite of what the noise and nuisance may be.

I want to give you an example. Last night, somewhere between 9 and 10 o'clock I was trying to listen to a particular television program I was interested in. Apparently the wind happened to be just right because these planes came booming over the Capital out of National and right over the hotel, and believe me, talk about interference, it even had me cussing. At the same time, I don't know what can be done; maybe nothing, in all probability. But the point I was getting at in my question is to what extent these traffic patterns and at what altitudes, safely, the pilot can bank either left or right to get out of a concentrated or heavily populated area.

Is it necessary for these planes to boom right in over the Capital here at certain times because of wind direction, or can they make a right bank and get out?

I think you understand the point at issue.

General QUESADA. I understand it very clearly, Mr. Sisk. I understand your interest is genuine and constructive.

In addition to saying that we do prescribe the pattern, we have the duty and responsibility to prescribe the pattern with definition. We are always confronted with the problem of balancing the equities.

I think that every member of this committee realizes that interstate and foreign commerce must continue.

Now, the continuation of interstate and foreign commerce should not continue, in my opinion, with disregard to the public. I think

the public, as you have suggested, has the right to look to us for their protection, and we have the duty to pursue their interests.

Whereas you suggested that you wouldn't support that nothing be done about it, we feel the same way. We think a lot should be done about it, by prescribing traffic patterns, prescribing minimum altitudes in various locations, and by prescribing areas over which the aircraft shall fly in departing and arriving.

We feel that we can, on the one hand, engage in reasonable interstate and foreign commerce, and, on the other hand, bring to the public the relief to which they are entitled.

I have no illusions that we are going to bring to the public complete relief, and I am sure, as a result of experience, that we are not going to satisfy all of them.

What we have to do and what we try to do is the best we can to balance the equities among all concerned.

Now, within that framework we have a requirement of enforcing the rules as we have prescribed them, often prescribed to bring benefit to the public, and this is not easy. But we do do it.

We are rather harsh on some occasions, and on many occasions very severely criticized, but of course this is an occupational hazard. [Laughter.]

But I assure you, sir, that this is one of our foremost problems.

Now, there is another side to this coin, Mr. Sisk, that I think is worth mentioning. If I recall correctly, in 1947 there was a series of tragedies in Newark, and there was a committee put together which is now known as the Doolittle Committee. And the Doolittle Committee came up with certain recommendations and suggestions and criteria for the development of airports in the future that were designed primarily to bring safety to the surrounding community, and they were not directed primarily at noise, although indirectly directed there.

For some strange reason, airports are magnets; they just attract people. So I think it would be unreasonable for anyone—and I am sure this committee is not unreasonable—to expect a continuous cycle of building an airport such as Idlewild or O'Hare, have the population encroach, then when they encroach the people complain about the noise that was there before they arrived, then close down the airport and build someplace else.

Now, I might add just for your interest: Here in the immediate vicinity of Idlewild, and at the end of an active runway, we have a new community that is now under construction, believe it or not. And their brochure advertises, with some satisfaction, such things as a public school planned by the city, a landscaped play area, parking facilities, shopping center.

Now, according to this brochure, there are something like 15 multistory apartment houses here. We were unable to stop this because the promoter for his own benefit saw fit to do this and by gosh, by gum, he has done so, and the place is right there, and these people are raising hell, if I may say so.

Right now in the immediate vicinity of Idlewild, there was and still is an application for a loan from a Government agency, the FHA, to permit the lending of Government funds to build a community right at the end of the runway.

By our interceding, we have persuaded the FHA not to grant the loan. As a matter of fact, the FHA is very, very helpful to us. They

are not granting loans to developments in the immediate vicinities of airports, which I think is constructive.

Now, the people, the promoter who is trying to build this development, he says: Well, the heck with the FHA, I will just go to the banks and get the money. And there is no way we can stop it.

I will come home closer, if you like.

Mr. SISK. I appreciate what you are saying because I realize this is the very thing that has happened. Of course, the many cases we have in California where actually property values now are dropping, because the people who found themselves underneath the jet runway—we have an Air National Guard operating now—and as a result several people told me, within the last 30 days, that they can't sell their property any more. The real-estate people take a person out and unless the homeowner can persuade the Air National Guard not to fly while the real-estate man is there [laughter], he can't sell it.

They shouldn't have been there in the first place. I agree with that.

This leads to the next question. To what extent do you feel or do you not feel that there should be some agency or some authority granted either in your agency or some other agency to prohibit the very thing you mentioned concerning Idlewild?

I think it is a shame that this type of situation can proceed to develop when tragedy will ultimately come in all probability, or else we are going to have many other problems.

Do you believe that inherent in some agency should not be the power to control that type of development?

General QUESADA. Let me express a personal opinion, and then let me lean on legal opinion.

Obviously I feel something should be done to prevent the type of thing that I have attempted to describe, which incidentally is occurring right here in Washington. Here we are abandoning Bolling Field and the Naval Air Station to permit a more orderly movement of traffic in this highly congested area, and by gosh, by gum, I woke up one morning and found that one of the planning commissions here in Washington is proposing and was planning to put on Bolling and Anacostia a housing development with multistory apartments.

Now, we were able to stop it, but this is the thing we have to be alert to every minute.

So therefore obviously I feel that there should be some means of stopping this sort of thing, other than by persuasion, which is the only tool that I have so far, or anybody has. I shouldn't be personal about it. I didn't mean to be.

Now, as far as the legal problem, I have expressed my personal views; maybe Mr. Howard would like to comment on the legal implication here.

Mr. HOWARD. This question does present some very difficult legal problems. Characteristically for the lifetime of this country the power to zone or prescribe the use of land in local areas has been in the local authorities.

There has been over many years a study and inquiry on the part of legal experts as to whether, to meet this particular problem, it would be possible for a Federal Zoning Act to be passed.

I think the consensus among those who have studied the problem from the legal standpoint is that a Federal Zoning Act would be of doubtful constitutionality.

It would not only be doubtful constitutionally, but it would tend to upset rather traditional divisions of powers between Federal and local authorities.

I think that is the key problem.

There have been other approaches to the problem, namely, the thought of model zoning acts for local application, and there is such an act in draft. I think the uniform law approach has some promise, but I think we all recognize that in an area where laws have such economic consequences, as they do in this case on the use of land, that the likelihood of wide adoption of a uniform law is remote, too.

That area of approach to this type of problem in the past has not been very productive.

Mr. SISK. Thank you, Mr. Chairman.

The CHAIRMAN. Will the gentleman yield?

I will ask Mr. Howard this: The military meets that situation by buying, at the time of the establishment of a military air base, a lien or a servitude over the air approaches. Should municipalities be induced to buy servitudes over the area around a municipal airport?

Mr. HOWARD. I think you have a very definite point, Mr. Brooks.

What we call avigation easements or noise easement approach is possible. As you know, on a national basis with tremendous airports involved and the concentration of populations around the airport, this can become a rather substantial bill to pay. It is, however, a possible solution.

The CHAIRMAN. Any questions?

Mr. Fulton.

Mr. FULTON. This is the first time I ever heard of a noise easement. Would there also be a sonic boom easement? [Laughter.]

You see, you get into problems where it gets so indefinite you almost lose your sequence.

Mr. HOWARD. From a legal standpoint you can buy, or in some instances condemn an interest in land which will permit you to do certain things, as the chairman pointed out, a servitude on the land.

Mr. FULTON. I was unaware that noise was any easement in land or any interest in land.

Mr. HOWARD. The right to make a noise and produce that much servitude on the land is a recognized easement. It can be so.

In fact, the Air Force has them in some areas.

General QUESADA. It might be interesting to note that in the construction of Dulles International Airport, which I must qualify by saying that we are just carving this airport out of the blue, so we are not inhibited by the events of the past, and it should be expected that we should take advantage of experience and history. I must also say that some communities have not.

We have acquired what we call buffer zones, which is that we have obtained title to land at each end of each runway, so I am referring to eight areas, and each of these areas is larger than the entire Washington National Airport, and there is not an inch of concrete there.

It is only to—it is designed for noise abatement and such problems as that. It is larger than the entire Washington National Airport, at each end of each runway.

The CHAIRMAN. Any further questions?

Mr. FULTON. Yes. I haven't completed. I didn't get started. [Laughter.]

The CHAIRMAN. If the gentleman will proceed.

Mr. FULTON. All right.

I guess it is for the reciprocal give and take of ideas that some of these committees are set up. So on that basis let me ask you: Had you ever thought of making takeoff runways underground and then have a landing runway on top of it? Had you ever thought of that?

The next thing is on——

The CHAIRMAN. Better let him answer that question. [Laughter.]

General QUESADA. I guess it is fair to say we have thought of it, but not for very long. [Laughter.]

Mr. FULTON. You could have the runway ascend from below, sort of a hill effect.

Representative BECKER. You are trying to make them fly like the Polaris at Idlewild. [Laughter.]

Mr. FULTON. You have said that 90 percent of the trouble on noise is on the ground, either on takeoff, rev-up, or coming in on the ground. I am trying to eliminate some of that ground noise.

General QUESADA. Just before you leave that, I feel that I must help out here because perhaps my remarks have been misunderstood.

When I refer to 90 percent of our problems occur in landing and takeoff, it is while the airplane is airborne, not while on the ground. It is while airborne during the approach and while airborne during the takeoff.

Mr. FULTON. You people have charge of such rules and regulations. Why don't you get ground control equipment that will take care of part of this? Or else have some method of cutting the engine off quickly. Why do they taxi with jet engines? I don't see that.

General QUESADA. Well, there are in some cases practices that employ towing. But I must say, Mr. Fulton, that the taxiing noises, though they have come to our attention and there have been many complaints, constitute a very small percentage of the problem.

There are suppressors for warmup purposes. We have by the processes of persuasion urged some of the companies to avoid these high thrust runups that are a part of maintenance, at 2 o'clock in the morning. This is right.

Mr. FULTON. I want to limit myself, sir, if I could move quickly to another question or two.

On the question of sound transmission in waves, of course the, nearer you get to a vacuum the less you have of the transmission of sound waves. Has there been anything done either on the possible use of vacuums as an approach on exhaust gases, or has there ever been anything done—I have been reading a book on the physics of particles, the excitation of particles—have you ever done anything about using magnetic fields around exhausts? Has anybody ever tried that?

General QUESADA. Well, in respect to the first, vacuum, of course, the noise is generated to some extent from the velocity of the exhaust gases and the exhaust gases, if they were exhausting into a vacuum I would say there would be no thrust.

Mr. FULTON. A consideration that might cause a partial vacuum of the side around the gases? Not that the gas is exhausted into a vacuum at all.

The next question is this——

The CHAIRMAN. Do you want your answer to that one?

Mr. FULTON. No, put that in later. I just want to get to this question. [Laughter.]

At the dedication of the Toronto Airport not too many months ago, we favored them very wonderfully by giving them an F–104 to fly by. The F–104 came in to dedicate the new municipal building and, incredibly, they flew by so fast and with such a shock wave that it did over $4 million worth of damage, so that they have to repair the building.

Do you know the altitude of that, the speed of it, and do you know the cause of the shock wave that caused that? Are we in the United States responsible for damage to the building in sending up an F–104 to show it off? We really caused damage.

Maybe you ought to ask your lawyer about that. Is the U.S. Government responsible for that?

General QUESADA. Well, in this particular case, I don't know whether we were even asked or whether we have volunteered or admitted responsibility. But in this particular case, the aircraft flew at supersonic speed at a quite low altitude.

Mr. FULTON. It did cause the damage.

General QUESADA. It caused damage.

Mr. FULTON. When that occurs, if the U.S. Government admits liability on that, maybe then it is going to have to admit to some damage on private individuals in this country, and maybe in some instances, that our good friend Bass speaks of, in New Hampshire.

So I am really not posing a single instance, I am proposing a thing that might be a practice. So what has been done on it? Are we going to pay for it?

Mr. HOWARD. Mr. Fulton, the earlier statement that Mr. Bass made to the effect that the Air Force has never responded in damages on a sonic boom case surprises me. If it is true, it is certainly something that is contrary to my previous understanding.

Mr. BASS. I had a slight qualification, Mr. Howard. Never to my knowledge. And I have knowledge of quite a few claims for damages.

They always send up an investigator who looks it over and always disallows it on the ground that the claimant can never prove positively—and the burden is on him, according to the Air Force policy—that the damage which was there was caused by the sonic boom rather than by some other cause.

Mr. FULTON. This is not my time, Mr. Chairman. [Laughter.]

The CHAIRMAN. The gentleman yielded.

Mr. FULTON. I have lost it.

Mr. HOWARD. I am not counsel to the Air Force, but I would think that there would be a claim, a legitimate claim for damage from a sonic boom. And I would think that in a case where damage was considerable and ascertainable as to cause, that the Air Force would have responded in damage.

I don't know that you are wrong. I just am surprised.

The CHAIRMAN. May I say to the gentlemen that counsel advises me we are already getting a list of those cases where claims have been paid.

Mr. FULTON. Good.

The CHAIRMAN. And we will put that in the record.

Mr. FULTON. Unfortunately, Mr. Chairman, I came prepared for this hearing, so I hope you will bear with me for one or two more questions.

The CHAIRMAN. The gentleman has been recognized. The gentleman had better use his own time and not yield.

Mr. FULTON. You say:

Our policy in regard to supporting research and development is that we are prepared to support work which has Agency approval by encouraging private industry, and secondly, when necessary and within Agency responsibility, by funding programs.

Would you please put in the record later a statement of those in more detail so that we have them?

General QUESADA. We will.

(The information requested is as follows:)

Mr. Quesada provided the following outline of the research program on aircraft noise control and abatement currently being conducted by the Bureau of Research and Development of the Federal Aviation Agency.

ASSESSMENT OF THE CURRENT NOISE PROBLEM AND THE STATE-OF-THE-ART IN NOISE ABATEMENT

(*a*) *Cost.*—$41,687; contract with Cornell Aeronautical Laboratory; plus the equivalent of 1 man-year BRD scientific personnel.

(*b*) *Time schedule.*—Initiated February 29, 1960; estimated completion date, September 15, 1960.

(*c*) *Description.*—This is a study of the entire aircraft noise problem, including (1) the impact of aircraft noise on the community, (2) what is being done and is planned to alleviate the noise problem, e.g., state-of-the-art in engine and suppressor design, and (3) what effective efforts are being made to alleviate the problem at the public relations level.

(*d*) *Results.*—The goal of the study is to pull together all of the existing research results and operational experience on the noise problem so that recommendations for immediate action can be made and that future research can be guided into the most productive channels avoiding duplication. An interim report on "Sound Barriers and Turbojet Engine Runup" has already been received from Cornell and is being acted upon.

RESEARCH ON SUPPRESSION OF NOISE AT THE SOURCE

(*a*) *Cost.*—Currently being conducted by BRD scientific personnel at the equivalent of one quarter man-year. An initial contractual effort is be considered with the University of Minnesota. Approximate cost $39,000.

(*b*) *Time schedule.*—In-house effort will be continuing. Initial contract would run approximately 9 months.

(*c*) *Description.*—Bureau scientists are compiling data on possible ways to suppress noise at the source and maintaining surveillance on the development of noise suppressors and quieter engines in the industry. Research by private industry is being encouraged. In cases where industry is not fully exploiting promising areas the Bureau will support contractual effort such as the University of Minnesota proposal to perform basic research on new concepts and configurations of engine silencers.

(*d*) *Results.*—As a result of the information compiled by Bureau scientists, industry is being informed of the amplitudes and spectural composition of noise reductions which would make appreciable inroads on the noise problem. Moreover, as this work progresses recommendations for engine and silencer performance standards may be promulgated.

RESEARCH ON AIRCRAFT NOISE CONTROL AND ABATEMENT ON THE GROUND

(*a*) *Cost.*—Currently being conducted by BRD scientific and engineering personnel at the equivalent of 5 man-years.

(*b*) *Time schedule.*—Initial experiments should not exceed 6 months.

(*c*) *Description.*—Using the Cornell Aeronautical Laboratory report on sound barriers as a starting point, Bureau personnel are computing the effectiveness, and costs of both fixed and portable sound barriers against noise generated by aircraft on the ground. Functional specifications for experimental barriers have been prepared for the erection of such barriers at the National Aviation Facilities Experimental Center. Tests and evaluations of the effectiveness of the barriers will be performed.

(*d*) *Results.*—Data compiled from these tests will enable the preparation of barrier design recommendations and provide guidance for airport design and regulatory action.

PSYCHOACOUSTIC AND HUMAN FACTORS RESEARCH

(*a*) *Cost.*—Currently being conducted by BRD scientific and engineering personnel at the equivalent of one-half man-year. As the planning phases of the work near completion the effort will be stepped up and contractual assistance will be required. Initial contract costs are estimated at $50,000.

(*b*) *Time schedule.*—This will be a continuing effort to keep pace with technological advancement such as the introduction of mach 2 and 3 aircraft. The initial phase of the work is on a 1-year time schedule.

(*c*) *Description.*—The first area being investigated is concerned with the physical characteristics of aircraft sound and its effects on people. Sound measurements are being taken at major airports which, together with existing data, are being used to up-date information on the relation of physical sound to community complaint. In addition, a study of the relationships between a prototype jet airport such as Dulles International and its surrounding community over a period of several years is being initiated.

(*d*) *Results.*—The results of these studies relating sound characteristics to human response willp rovide guidance for regulatory action and greatly assist in airport planning and public relations work.

ANCILLARY NOISE REDUCTION RESEARCH

Description.—Other research of the Bureau, although primarily oriented toward safe and efficient air traffic control, has important bearing on the noise problem. Any device or procedure which enables aircraft to fly with greater accuracy leads to better control on course in landing and takeoff and thus more effectively confining aircraft noise to prescribed areas, such as approaches over water or industrial areas. Work on visual-glide-path indicators, automatic landing systems, design of parallel runways, improved air traffic control equipment and procedures, etc., all contribute to the accuracy of flight. Research of this type is a continuing responsibility and constitutes the major portion of the budget.

Mr. FULTON. I would like to see the kind of programs and the aiming of them.

Finally, on the energy that is produced by noise and sound in these engines, have you understood that the Soviets might be using it for an added propellant, rather than considering it a defect? We have had nothing but testimony on how to get rid of noise. They are turning it into propellent energy, and there is some inference they have.

General QUESADA. We will look this up.

Mr. FULTON. Earlier in the New York Times, Tuesday, November 5, 1957, and the Providence Journal of that date, "Two scientists reported on new sources of power in a Moscow radio broadcast, V. I. Dikushin, a noted authority on mechanics," and a man identified as N. N. Andrekev, and he is described as an "expert in acoustics."

General QUESADA. Sir, I am going to Moscow next month, so I will ask about this.

Mr. FULTON. I will give you these and you can take them with you. (The newspaper articles above referred to are as follows:)

[The New York Times (city edition), Nov. 5, 1957, p. 1, col. 8]

NEW SCIENCE SEEN

MOSCOW ANNOUNCES THE DEVELOPMENT OF NOVEL CONTROLS

(Text of Tass dispatch will be found on p. 12)

By the United Press

Moscow, November 4.—Russia announced tonight that new sources of power had been used to hurl the second satellite into space.

Two top Russian scientists reported that the half-ton size of the satellite "necessitated the development of improved new instruments and sources of power." They did not explain what the new sources of power were.

The two scientists who reported on the new sources of power in a Moscow radio broadcast were V. I. Dikushin, a noted authority on mechanics, and a man identified as N. N. Andrekev, "an expert in acoustics."

Another scientist, a Professor Stanyukovich, described the new satellite as having a "very elongated shape." This confirmed the Western belief that the second satellite was not a sphere like the original satellite but rather the conical nose of its launching rockets.

Mr. Dikushin said in his Moscow radio report that a "multistage carrier rocket of a new design with foolproof precision controls had to be used for the satellite to get into its orbit."

Mr. Andreyev said the launching of the second satellite was not an "isolated breakthrough" but rather a "solid mastering of a new branch of science and engineering, the importance of which it was difficult to overestimate even today."

[The Providence Journal, Nov. 5, 1957, p. 1, col. 8]

RUSSIANS MUM ON DETAILS, SEE GREAT PROGRESS

(Compiled from press dispatches)

Moscow.—Russia announced last night that new sources of power had been used to hurl Sputnik II into space.

Two Russian scientists reported that the half-ton size of the satellite "necessitated the development of improved new instruments and sources of power." They did not explain what the new sources of power were.

The scientists were V. Dikushin, an authority on mechanics, and a man identified as Andreev "an expert in acoustics."

(Text of Tass dispatch on Sputnik II, p. 7.)

Another scientist, Prof. Kiril P. Stanyukovich, described the new satellite as being different from the first one in that, "Being the last stage of the rocket, it has a rather elongated shape."

"Its dimensions are rather complex because of its shape," he said. "But we can say its length exceeds its average width by many times."

PRECISION CONTROLS

Mr. Dikushin said in his Moscow radio report that a "multistage carrier rocket of a new design with foolproof precision controls had to be used for the satellite to get into its orbit."

Mr. Andreev said the launching of Sputnik II was not an "isolated breakthrough" but rather a "solid mastering of a new branch of science and engineering, the importance of which it was difficult to overestimate even today."

Moscow radio said that Sputnik II was carrying a "special installation" for the study of primary cosmic rays.

The CHAIRMAN. Any questions here?

Mr. DADDARIO. I had one adaptation of a question just asked by Mr. Fulton. I would be interested in receiving a copy of the reply to Mr. Fulton's last question concerning your programs, helping industry and funding of programs, and I want to ask you just one question beyond that.

On pages 13 and 14 you referred to General Electric lowering or suppressing sound by 9 db.

We have had testimony here by Pratt & Whitney that they have a 10 db suppression in their turbofan engine.

I would like to know, also, and you can put this in the record, the comparable figures in the rest of the industry so far as their development of suppression of sound.

General QUESADA. We will get that for you.

(The information requested is as follows:)

Mr. Quesada's statement referred specifically to General Electric and intentionally omitted reference to Pratt & Whitney with the understanding that Pratt & Whitney would make its own statement to the committee. There are no other U.S. engine manufacturers with hardware currently developed for commercial jet transport application. Therefore, the sound suppression figures for General Electric and Pratt & Whitney are the only applicable figures available at this time.

The CHAIRMAN. Mr. Hechler?

Mr. HECHLER. General Quesada, I think maybe we have the perfect solution in West Virginia, because as you know the only place we can build an airport is to cut the top off a mountain. [Laughter.]

And then at Huntington and Charleston and Elkins, and other places where we have done this, we don't run into this noise problem.

Of course, I know other States are not as fortunate as West Virginia in that, but, I wonder, is there any way in planning future airports where you could put them where there are a lot of rattlesnakes or mosquitoes, or someplace where you won't run into some of this trouble?

General QUESADA. The location of an airport is the responsibility of the community. If the city wanted to put an airport in Central Park, the city of New York wanted to put an airport in Central Park, as far as we are concerned we would come into the picture in two areas:

If they asked us to contribute to it, we would say no.

So in that regard, in the distribution of Federal funds for the aid to airports, we are giving consideration to the noise-abatement problem, and whereas we are often held in ridicule for denying funds for this reason, we are nevertheless denying funds when we would be encouraging a situation that is unreasonable.

Mr. HECHLER. Yes.

General QUESADA. Now, the city of New York could put their airport in Central Park, except we might not let them use it because it would interfere with the traffic at Newark and Idlewild.

The thrust of what I am trying to say is that the location of airports throughout the country is the responsibility of the community.

Mr. HECHLER. Sure.

Just one further question, Mr. Chairman.

Now, is there anything that Congress or this committee can do in order to help FAA and help other agencies interested and active in this problem?

I noticed, for example, that in one portion of your testimony you used the phrase "within the terms of the law." I wonder is there any way that we could amend or broaden the authorization in your legislation or provide additional funds for research or do anything that would speed the program that you are undertaking in this field?

General QUESADA. We have made reference to the law, and there is considerable doubt in our mind as to whether the law does place

upon us the responsibility of writing and establishing rules for noise-abatement purposes.

I think it might be well if my legal counsel commented on this, because he is minutely familiar with the specific provision of the law.

Mr. HOWARD. I think I might go back to the earlier statement that Mr. Quesada made.

On the problem of noise as it was treated when our agency was established in the Federal Aviation Act of 1958, Congress was not really focusing on the noise problem at that time. They did put into the act the language we have already referred to, the authority to prescribe air traffic rules for the protection of persons and property on the ground.

This latter phrase was a general phrase, however, and in the hearings on this legislation the instances cited as probable areas for the use of this authority were such things as spraying of crops and other uses of airspace, not specifically the noise area.

We, I feel, have stepped up to the plate, if you want to put it that way, in interpreting that literally. That is, interpreting it as a protection of persons and property on the ground even from noise.

I wanted to make that clear because I don't think that even with the act as it now stands, although I consider that a court would rule that it covered noise, that Congress really faced up to the problem of noise.

Now, in another area which has been mentioned here, it is quite clear to me that the power to prescribe noise standards is missing from the act.

The fact that Congress used this phrase "for the protection of persons and property on the ground," only in the air traffic rules section of the act makes it clear that reference is to just safety, air safety or safety in air commerce elsewhere in the act did not extend any further than the traditional previous use of those terms.

I feel, for example, that this question that arose earlier as to whether we could prescribe standards or noise criteria for the performance of engines or aircraft is clearly not covered by the act as it is now written.

I would say that there are good reasons why there should be some such provision in the act.

I might point out that those who are engaged in developing engines and aircraft are competing with each other for performance for an aircraft that will do work and do it efficiently and cheaply. This leads them to build into engines and aircraft maximum performance characteristics without regard to noise.

If there is no general limitation on noise criteria there certainly is no incentive to each developer to adhere to some standard that he may worry about whether his competitor is adhering to, if I make myself clear.

Mr. HECHLER. Well, I hope that your Agency will submit to the committee—and I certainly will be interested personally in any additional suggestions that you have for amendments of the act so that we could move forward in this very important field.

General QUESADA. This has been discussed, sir, in the Interstate and Foreign Commerce Committee of the House, in hearings there. And there is a general belief that, on the one hand, there is a lack of such authority, and, on the other hand, there is a requirement for such authority.

The CHAIRMAN. We are fortunate here today in having with us one of our colleagues from the House Armed Services Committee.

The chairman, with modesty, says that he was a member of that committee for 22 years, and we are very happy to have Mr. Becker here.

Mr. Becker, before we adjourn, have you any questions you would like to ask?

Representative BECKER. Just one or two.

I certainly miss you on that committee. We miss you there but you are lending greater effort here.

First, I would like to pay a compliment to this man, General Quesada, because I don't know anyone who is running an agency who is up against more occupational hazards, as he put it, because he is hit from all sides, whether it be people on the ground, commercial airlines, pilots, and the Air Force. Everybody, generally, is against General Quesada. But I compliment you because I don't know of anyone who is trying to do a better job than you are.

General QUESADA. You are very kind.

Representative BECKER. Only a week ago today at the request of Congressman Derounian and myself you visited our districts, which are adjacent to Idlewild Airport. The point I would like to ask you is the question of these rules affecting the takeoffs and the landings, particularly as to violations as to height and the patterns coming in.

How soon do you expect these will be promulgated or brought into being?

General QUESADA. Sir, as you know, and as you have expressed such genuine interest in the proposed rule which has been published in the Register and toward which we have received comment, and it now rests upon us either to publish a rule or not to publish a rule as it applies to Idlewild, I must tell you that the rule that is to be published is now on my desk.

You should expect a rule to be published prior to September 4, which is when I go to Russia. I'm not publishing a rule and then going to Russia. [Laughter.]

The CHAIRMAN. Does the situation justify that? [Laughter.]

General QUESADA. It isn't quite that bad, Mr. Brooks.

But you should expect the rule to be published within a week, and I am confident that it will bring some relief to the community in which you have such a genuine interest and whose interests you pursue very vigorously, I might add. [Laughter.]

It isn't going to eliminate the problem. It is going to bring relief to the problem.

I can assure you one thing that it is our intention to enforce it once it is published.

Representative BECKER. I might point out here, because questions were raised: We have organizations up there, as you know, that are in an absolute state of revolution. They are threatening now to create a scene of an automobile parade over to Idlewild Airport and block the runways and everything else, because they just can't live with this condition.

I have it myself because I am in the area, 5 or 6 miles away from Idlewild. When one of those 707's comes over my house, Mr. Sisk, we don't get television interference alone, our churches can't even proceed with their services.

This is absolutely disastrous, children are ducking under the tables these things are so low.

Now, there are violations as to flying patterns. They come in and instead of being 5 miles away in hitting the signal there and coming down at 1,500 feet in a 3 degree glide pattern, apparently from pictures that have been taken, they are down way under this altitude.

And these are things that, Mr. Chairman, I hope through your hearings and others there will be a possibility of correcting.

General QUESADA. And you have the right to expect it. To the extent we can, they will be corrected.

Representative BECKER. We have got to do it or, as the gentleman from West Virginia said, we have got to have some legislation.

The villages of Cedarhurst and Lawrence did have legislation. They are in my area. These were thrown out by the courts.

Now, a group of lawyers are getting up funds to take the type of cases mentioned by Mr. Fulton into courts to argue the point that they are interfering with what people believe is their constitutional rights, pursuit of happiness, quiet, and comfort.

Now, these things will probably wind up in court. What the suits or claims will be against the commercial companies or the Government, I do not know. But they are all part of this scheme of things, and that is why something has to be done.

Just what will be done I don't know. But I certainly hope that you will be successful at least in this part of the picture in preventing these violations.

Mr. Chairman, that is all I have to say at this time, and I appreciate your kindness.

The CHAIRMAN. Our colleague is very diligent, as you can see, and he seems to be disturbed. I commend his thoughts to your attention, General.

Mr. Laymon N. Miller earlier testified before this hearing that the FAA rulings would relax the regulations of the New York Port Authority in this respect and the situation might actually be worse there.

Now, I would like for the general to say what he feels in reference to that.

General QUESADA. Well, Mr. Miller is an employee of the New York Port Authority [laughter] and I respect his views, certainly. I am not unmindful of what I have just said. I don't agree with him. I disagree with him. I disagree with him quite thoroughly, if I may say so.

I am sure, sir, that any group could hire a consultant and come up with a solution better than ours, at least in their minds. [Laughter]

We are confronted with the almost impossible task of satisfying everybody. We just have to do the best we can, establish, and recognize that there are these legitimate interests, that there is this damage to the people on the ground, that they are entitled to some assistance and protection from those with authority.

We have to balance this with the necessity of interstate and foreign commerce. We have to give consideration to the elements of public safety, and our job is to balance the equities and be as just to all as we know how.

The CHAIRMAN. At any rate, General, you are aware of the regulations of the New York Port Authority?

General QUESADA. We are; yes, sir.

The CHAIRMAN. And you are taking that into consideration, aren't you?

General QUESADA. We do.

The CHAIRMAN. In making up your regulations?

General QUESADA. We consult with the port authority in great detail. And I must say that they recognize the problem that is ours and we try to recognize the problem that is theirs, and they are extremely helpful to us.

The CHAIRMAN. One more question which has been handed to me by our able counsel.

With the introduction of foreign aircraft in the United States, the British Comet, for instance, or the French Caravel, should there be some international group created to work with foreign manufacturers so that they may know the criteria that this country has established and may design and pattern their engines and their airframes accordingly?

What do you think of that?

General QUESADA. There is such a group, ICAO, a part of the United Nations. They do have a rather active noise abatement activity. Such a group exists today.

The CHAIRMAN. Fine.

Thank you very much, General. You have given us very fine testimony. We appreciate your cordiality, too, in coming before the committee. We will welcome you back at any time.

General QUESADA. I hope you will let me come back.

The CHAIRMAN. The committee has agreed to hear one additional witness. He understands, however, that our time is limited, and if there is no objection I would think it would be better to hear him now because that will wind up the hearings.

The witness that I have in mind is Mr. B. S. Spano, director of Polysonics, Inc. He is from Washington, D.C.

Mr. Spano, if you will come forward, sir.

We may have to abbreviate your testimony because it is now after 12, and we are a little bit under pressure in this Congress.

Mr. SPANO. Thank you very much, Mr. Brooks. My testimony should take about 10 minutes.

The CHAIRMAN. Do you have a prepared statement?

Mr. SPANO. Yes, I do have a prepared statement, but I am making some changes in it as I proceed.

The CHAIRMAN. You don't have copies?

Mr. SPANO. No, I am sorry, sir, but I will provide the committee with adequate copies.

The CHAIRMAN. Just proceed, sir.

Mr. SPANO. Thank you.

STATEMENT OF BARTHOLOMEW S. SPANO,[10] DIRECTOR, POLYSONICS, INC.

Mr. SPANO. My name is Bartholomew Spano, director of Polysonics, Inc. I have been active in the acoustical and psychoacoustical fields of community jet noise problems and in the Government planning of jet airline operations domestically and internationally for a number of years.

I deeply appreciate the opportunity to testify before your committee.

I am not associated with any elements of the aviation industry and will speak impartially on certain purely scientific aspects of the aircraft community noise problem.

Because my time is brief, I will consider only three major subjects on noise:

1. Man's noise complaint mechanism.
2. Scientific aspects of the PNdb system.
3. Immediate noise control measures.

1. MAN'S NOISE COMPLAINT MECHANISM

We have heard testimony this morning that many millions of dollars has been devoted to jet noise suppression research and development. This tremendous effort is directed toward one thing—reducing community complaints over noise.

Thus, man's noise complaint mechanism is the vital key to noise control. It must be thoroughly explored and understood, and in fact establishes the noise control objectives for the engine designer, aircraft designer, airline operator and the airport planner, and the Government agencies.

In short, the psychoacoustics of the airport community determines aircraft noise design and operation.

I hasten to explain the term psychoacoustics. It means simply man's psychological reactions to the sounds he hears. They may be pleasant, unpleasant, even terrifying, or even make him willing to donate funds to an antinoise committee.

It is a very complex subject. It requires a great deal of work.

I urge the committee to support basic research in the study of man's noise complaint mechanism so that we in aviation noise control can more effectively do our job.

2. SCIENTIFIC ASPECTS OF THE PNdb SYSTEM

The PNdb system which we have heard mentioned a number of times: we have some support of the system, and we have some groups that disagree with it in part or in whole.

[10] Bartholomew S. Spano, director, Polysonics, Inc.: 1947–60: Aircraft Noise Authority, Federal Aviation Agency; Chief, Noise Abatement Team, FAA; Chief, Jet Planning Team, FAA; Chairman and U.S. representative to the International Civil Aviation Organization Jet Operations and Planning Panels (1956–60); FAA member NASA Aircraft Noise Subcommittee; FAA member Committee on Hearing and Bio-Acoustic Committee; planning expert for supersonic transport facilities. 1942–47: U.S. Air Force Headquarters; active duty Air Material Command. 1941–42: Bureau of Aeronautics, U.S. Navy, Washington, D.C. 1939–41: National Advisory Committee for Aeronautics, Langley Field, Va. 1938–39: Sealand Aircraft Co., N.J. 1934–38: Bachelor of aeronautical engineering degree, New York University; registered professional engineer, District of Columbia; member, Acoustical Society of America; member, Society of Automotive Engineers; authored NACA technical reports; chairman, SAE session on aircraft noise, national aeronautic meeting, New York, April 6, 1960.

A scientific evaluation of this system in its basic concept and in its translation into airport restrictions raises some very serious doubts. If, for example, 112 PNdb is set as the summertime standard and we know scientifically that in the wintertime with windows closed and the improved performance of cold weather jet operations that the complaint motivation is markedly less—then using the same 112 PNdb as the wintertime limit, as is the case at a major airport today, using this same 112 PNdb limit is overrestrictive and scientifically indefensible.

We have heard of man's ability to adapt to high noise levles. We know of the Viscount experience wherein its shrill whistle in early operations caused a distinct community noise complaint pattern. But people became adapted or worked down their "listening-learning curve," as I call it, on the Viscount, and there is no community complaint pattern peculiar to the Viscount today.

The PNdb system fails to take into account this very real scientific phenomena of adaptation or listening-learning.

For this next point, I would like to set up a chart. It would take less time to do it that way.

I am going to improvise here a little bit to hold this chart up. I hope it will stand. I am going to apologize to the audience, but perhaps my explanation will help a little bit.

The CHAIRMAN. May I say this to the witness: We have had the first bell on the quorum call over on the floor of the House. We will have the second one, I would say within the next 5 minutes.

Mr. SPANO. I expect to be finished before that time.

The CHAIRMAN. We will have to adjourn, regardless, at that time.

Mr. SPANO. Yes, sir.

The PNdb system ostensibly attempts to equate the "noisiness" of a large piston transport to a jet transport. The PNdb system, in essence, weights a noise with high frequency since we as humans hear the high frequencies louder than the low frequencies. So a jet noise which is somewhat higher frequency than a piston engine noise will read higher on the PNdb scale. For example, 108 db of a piston engine, let's say for this demonstration, equals 112 PNdb, but a jet, because of its higher frequency content of, say, 100 db also equals 112 PNdb, because the higher frequency content rates it higher.

But this is the daytime standard. For nighttime use the formula, let's say the formula daytime then is a jet can make 100 db, just speaking rather roughly in these figures, 100 db on a sound level meter in the community.

A piston engine can make 108 db, because being a lower frequency it is supposedly a little more tolerable. But the nighttime standard is 108 db for a piston engine.

But for a jet, it is zero db, because jet operations are prohibited except off one runway at this particular airport.

Again, this is an overrestrictive arrangement. If you can in the daytime equate one noise level of a piston to the jet as 100 equals 108, you can do it the same by the same token for nighttime operation. To say that 108 db arbitrarily equals zero db is also of a restrictive, and scientifically indefensible.

These are only some of the scientific questions in regard to the PNdb system. Time does not permit more.

It was an excellent first step toward trying to determine this question of complaint motivation. I feel it is premature and a great deal more work is required, and I feel that I am not speaking alone in that statement.

3. IMMEDIATE NOISE CONTROL MEASURES—THE FINAL POINT

We have talked enough about noise measurement systems and studies. Now let us talk about actual noise control measures we can put into immediate use.

Community noise complaint motivation is the result of the sum total of all the high intensity noises experienced by a community from an airport or airbase, that is, both aircraft flight noise and ground noise.

Aircraft flight noise, we know, is most difficult to control because of serious safety aspects. This, however, is not so with ground noise which is also a serious problem, particularly at night and contributes a major share to man's overall complaint motivation toward aircraft noise.

Ground runup noise can be reduced by mufflers which are available today. Perhaps they are not as perfect as we would like and perhaps they will be better next year and still better the year after.

The need for noise control at jet airports and bases is now, and available equipment should be put to use now to relieve the ground noise portion of the overall noise problem.

We have talked a lot about noise problems at this hearing and about the noise of the jet age—but let us take a look at its broader implications.

The jet age is approaching its second year—with a perfect passenger safety record and with many millions of passenger-miles flown. The public has taken to jet transportation in a grand style, and travel concepts and thinking in many fields are changing.

This remarkable improvement was not achieved without tremendous effort, financial risk, and great dedication on the part of the aircraft, engine, and airline industries, the airports and the FAA, to make this radically new type of transportation that flies in a more critical flight regime, and which is more demanding and exacting to make it the safest and best transportation in history.

The aviation industry has risen magnificently to this great challenge, and yet do we hear words of thanks and congratulations for this accomplishment? No; the only comments seem to be complaints, noise complaints.

They are justified, but the industry and Government will ameliorate the noise problem, and are treating it with the great respect it deserves.

I would simply like in conclusion to pause for a moment during our intensive noise-control work to set the jet age in perhaps a little better perspective, and as an individual I would like to express my deep appreciation for the tremendous job industry and Government has done in bringing the safest, finest air transportation system to the United States and to the world.

Thank you, very much.

The CHAIRMAN. Thank you very much, Mr. Spano.

The committee will stand adjourned sine die.

(Whereupon, at 12:17 p.m., the committee was adjourned sine die.)

APPENDIX

HOUSE OF REPRESENTATIVES,
Washington, D.C., August 30, 1960.

Hon. OVERTON BROOKS,
Chairman, Committee on Science and Astronautics,
House Office Building, Washington, D.C.

DEAR CONGRESSMAN BROOKS: I enclose a statement in connection with the committee's hearings on the problem of noise.

If possible, I should appreciate the insertion of this statement as a part of the record.

Sincerely yours,

PETER W. RODINO, Jr., M.C.

STATEMENT OF CONGRESSMAN PETER W. RODINO, JR., REPRESENTATIVE, 10TH DISTRICT OF NEW JERSEY

Mr. Chairman, may I first extend my personal congratulations to this committee for undertaking to investigate one of the major problems of modern civilization. Our scientific and technological achievements have brought with them a rapid increase in noise which permeates our communities and disturbs and distresses our citizenry. So far, we have tended on the whole to accept the good with the bad, and have failed to give this problem the attention it deserves. But the increasing impact of noise on our health, our comfort, and our daily life makes it imperative that we attack the problem frontally and work out effective solutions. There is, after all, no reason why the scientific expertise which has transported us into this technological age cannot come up with equally effective answers to some of the problems which technology has left in its wake.

Mr. Chairman, I am proud to represent the 10th District of the State of New Jersey. It is my purpose in this statement to convey to the committee my district's deep concern with the problem which is the subject of these hearings.

For the citizens of the 10th District, noise—and particularly airport noise—is hardly a new problem.

Back in 1956 the mayor of Newark, N.J., myself, and several other members of the congressional delegation received so many complaints arising from the noise of low-flying planes using Newark Airport that we scheduled conferences with officials of the Civil Aeronautics Authority to determine what could be done about it.

Subsequently, some of the air traffic was diverted from the more populous areas by what, as I recall it, was a new runway and instrument approach system. The situation has been somewhat ameliorated, but the long-range problem remains.

Our citizens were so aroused at that time, I might add, that they formed a citizens' group to seek relief through the courts. Air traffic was then increasing at the rate of 20 percent each year, and jet-plane operations, particularly from military training flights, had already become a problem.

Needless to say, the solution does not lie in curtailing air operations, which are essential to our local and national economy. Nor can airports often be located away from cities, whose commercial and private needs require ready access to air terminals. It will only be through technological research and proper planning that the eventual means will be found by which our air facilities can continue to expand without disturbing the local residents.

The greatest problem, in my opinion, is to determine just who has responsibility for developing the technology and for insisting upon its utilization. The airport conferences which we held in 1956 were frustrated when the CAA revealed that it had no authority over the noise problem, but could regulate only with regard to safety. Local officials, on the other hand, had no control over the Newark Airport and could do little except make known their protests.

I do not know how much authority the Federal Aviation Agency, as successor to the CAA, has over the control of noise, or how much authority it has in fact exercised. These hearings will make a most significant contribution, in my opinion, if they specifically pinpoint that responsibility. The noise nuisance from air operations will be abated only if we recognize that noise control must be an inherent part of airport planning and airport policy.

The first step, of course, is national awareness that noise is a problem, and that noise must be controlled. I personally, and, I believe, every citizen of the district which I represent, are grateful to this committee for promoting that awareness by these hearings.

NOTE.—Since time was a limiting factor, it was impossible to hear all interested agencies, industrial concerns, and investigators in the field. The committee, therefore, invited a select group to contribute written remarks on the noise problem to insure that a meaningful cross section of opinion was available.

A letter, such as the following sample, was sent to the majority of the group from whom responses were desired.

JULY 15, 1960.

Mr. ———, ———
———, ———.

DEAR — ———: The U.S. House of Representatives Committee on Science and Astronautics has scheduled 3 days of hearings on the problems of noise and its effects on men and machines. These hearings are scheduled to begin on August 16, 1960, in the committee hearing room, 214–B, New House Office Building, Washington, D.C.

The interest of the committee centers around the research and development associated with psychological, physiological, and engineering problems involved in jet aircraft, guided missile, and rocket operations. The committee is particularly interested in the problems associated with designing noise out of these systems without loss of efficiency in design. In order to acquaint the committee with the technicalities of the problem, the staff is engaged in an investigation to determine what research and development is going on in this area.

Since time is regrettably limited, it is not possible to hear all of the qualified witnesses who represent the various Government agencies, industry, and other private organizations that have an interest in this matter. You are at this time, however, invited to submit your observations, suggestions, and recommendations for inclusion in the record. If you desire to provide material for inclusion in the investigative report in lieu of the record, it would also be welcome. The committee is particularly interested in having the benefit of your views to insure the development of a meaningful report.

To assist you in preparing your views on the subject of noise problems, the following specific points are considered of interest to the committee.

1. An estimate of the dollar effort you have invested in research, development, test, and evaluation in the area of noise suppression in your aircraft, rocket, and missile development.
2. Does your organization have an established noise and acoustical laboratory?
3. Does your organization retain consultants in the field of noise and bioacoustics, such as Bolt Berenak & Newman Co.?
4. Can you comment on the adequacy of the acceptable noise parameters as set forth by the FAA?
5. Can you discuss the noise problems associated with the design of a supersonic transport covering such things as sonic boom, sonic structural fatigue, and problems associated with takeoff and approach noise reduction.
6. Do you feel that there is a coordinated program, both in Government and in private industry which is oriented to solve the noise problem?
7. Do you feel that the problem is receiving overemphasis?
8. What are the serious noise problems associated with the static testing and flight testing of large rockets and missiles?
9. Does your organization study the psychological and physiological problems of personnel who work in a noise environment around jet aircraft, rockets, and guided missiles?
10. Do you feel that the National Aeronautics and Space Administration is devoting sufficient effort in the area of noise studies which would lead to the solution of your problems?

11. Have you been confronted with legal problems resulting from noise generation associated with your development efforts?

It is certain that your contribution to these hearings will result in the development of a meaningful report. If possible, the committee would appreciate receiving your reply prior to the date the hearings are scheduled to begin.

I should like to thank you in advance for your cooperation.

Sincerely,

CHARLES F. DUCANDER,
Executive Director and Chief Counsel.

DEPARTMENT OF COMMERCE,
NATIONAL BUREAU OF STANDARDS,
August 4, 1960.

COMMITTEE ON SCIENCE AND ASTRONAUTICS,
House Office Building,
Washington, D.C.

GENTLEMEN: In accordance with a recent telephone conversation between Captain Silberstein of the Committee on Science and Astronautics and Dr. Richard K. Cook of the Sound Section, enclosed is the report on "Reduction of Aircraft Noise."

Very truly yours,

A. V. ASTIN, *Director.*

WORK OF THE NATIONAL BUREAU OF STANDARDS ON REDUCTION OF AIRCRAFT NOISE

During the past 30 years the National Bureau of Standards has done a considerable amount of work in the field of aircraft noise reduction. Most of the earlier work was directed toward reduction of the noise heard in the cabin of a propeller-driven airplane. The results were summarized in a comprehensive report entitled "Principles, Practice and Progress of Noise Reduction in Airplanes," by Albert London. This report was prepared for the National Advisory Committee for Aeronautics, NACA Technical Note 748 (1940). It dealt with the broad aspects of the problem; as well as the detailed technicalities. The latter involved studies of the numerous sources of noise in aircraft and the techniques for soundproofing aircraft cabins.

In recent years the work has been directed toward basic studies of the aerodynamic mechanisms which give rise to jet noise. These researches included measurements of the spectral distribution and total power radiated by model subsonic air jets. Various nozzle configurations were investigated, including nozzles having circular or elliptical cross sections and terminated with square-edge, saw tooth, or corrugated ends, of the type currently in use on some jet engines. A similar study involved measurements on several air jets operating simultaneously.

Other recent projects dealt with sound attenuation measurements on cylindrical sound absorbers used for quieting jet engine test cells. Related projects involved sound level measurements on two turbojet engine test cells for the purpose of testing the facilities for compliance with the acoustical requirements of Federal specifications.

Sound transmission loss measurements on three types of fuselage structures have been carried out. Advice on the design and construction of sound insulated buildings has been provided for Air Force and naval air stations.

MCDONNELL AIRCRAFT CORP.,
St. Louis, Mo., August 5, 1960.

Mr. CHARLES F. DUCANDER,
Executive Director and Chief Counsel,
Committee on Science and Astronautics,
House of Representatives, Washington, D.C.

DEAR MR. DUCANDER: Your letter of July 18, 1960, addressed to Mr. J. S. McDonnell has been referred to me for reply. Questions posed in the inquiry are answered in the order in which they appeared.

1. The company has expended in excess of $2 million for services, personnel, and hardware affecting noise, noise control, noise attenuation, and

sonic effect on structures and components. A considerable sum has been spent for design, development, and construction of devices designed and installed to protect the community surrounding the airport and the MAC plant, and MAC employees working in high noise level areas. Modern facilities and equipment have been installed in MAC's new laboratory facilities for the study of sonic effect on structures and components.

2. The MAC Sonic and Acoustical Laboratory and equipment may be divided into three area according to objectives. The first deals with community relations and inplant personnel relations. Specially trained people with the latest equipment have, for a period of approximately 10 years, constantly monitored these two areas to minimize disturbance and injury. With regard to personnel, the company has had established for some time a hearing conservation program which involves periodic hearing tests of employees exposed to high frequency and energy sounds. This program has been quite extensive and successful.

The second is sonic effect upon structures. The theoretical studies of the problem are carried on in the structural dynamics department, which includes people of special and specific capabilities in this area. The actual physical test is carried on in the structures laboratory where special facilities and equipment are available.

3. Outside consultants have been retained from time to time for approximately 10 years to study various noise and bioacoustics problems. The studies cover the range from soundproofing a prototype transport aircraft through evaluation of effectiveness of outside muffling devices and noise level and attenuating capabilities in new buildings and offices.

4. No comment can be made on the probable effect of the FAA recommendations entitled "Noise Abatement Procedures," issued June 1960. Such procedures do not apply to the operation of military equipment tested by M.A.C. as these aircraft exceed in performance the minimum standards of the procedures. The aircraft are operated at climb-out angles and close landing patterns, minimizing the noise problem.

5. McDonnel has not produced a supersonic transport nor studied the specific noise problems related to this type of aircraft.

6. There is a constant and continuing effort both in industry and Government which recognizes the existence of the noise problem. As the field is relatively new, it would appear that the various seminars and conferences held by varying groups such as the AIA, University of Minnesota, etc., serve a very useful purpose as a forum of exchange of information and for the settlement of criteria.

7. We do not feel that the noise problem in certain areas is receiving overemphasis. For instance, the effect of sonic vibration or pressure on structures and components, although relatively a new problem, is one of considerable magnitude requiring constant surveillance and work. Although we have not experienced a noise problem in the St. Louis area, we feel that the industry and operators and the Government agencies should continue to emphasize work in the areas as it poses a potential inconvenience of considerable magnitude to the community, and has been illustrated by a number of cases, a potential threat to expanding aviation.

8. The principal line of the company's business has not given it prime responsibility for the testing of large rockets or missiles and, although we have from time to time been engaged in the testing of such rockets and missiles, these tests have been upon Government reservations under control conditions where noise problems are at a minimum. We do not feel, therefore, that we can give an authoritative answer to this question.

9. As indicated in the answer to No. 2, the company has organized and has had in existence for a considerable number of years, an extensive well-regulated program of hearing conservation for employees. This program involves the determination of areas where the noise level is such as might physically affect an employee. Employees in such areas are provided protective devices and constantly surveyed through the medium of audiograms supervised by trained personnel and monitored by physicians. This program has proved to be extremely successful.

10. The company has participated in and been coordinated with the National Aeronautics and Space Administration's efforts in studies on the effect of sonic vibrations on structures and components and feels that the NASA program is significant.

11. The company has not encountered legal problems resulting from noise. Inasmuch, however, as the noise problem is receiving considerable publicity

and emphasis around airports with the bringing into service of large passenger jets, McDonnell has participated in forming an informal noise committee on Lambert-St. Louis Municipal Airport. The object of this committee is to constantly monitor the airport operations and the operations of fixed-base operators, and to provide a forum in the event, at some point in the future, noise problems may arise.

The foregoing is but a very brief outline of an extensive and integrated program involving considerable expenditures by McDonnell in the fields of community relations, personnel relations, and structural studies. We sincerely hope that this outline may be of some assistance to the committee.

If the committee desires more detailed information, we will be most happy to furnish what we have upon request.

Yours very truly,

ROBERT W. GILCREST, *Assistant Secretary.*

VOUGHT AERONAUTICS,
Dallas, Tex., August 5, 1960.

Mr. CHARLES F. DUCANDER,
Executive Director and Chief Counsel, Committee on Science and Astronautics, House of Representatives, Washington, D.C.

DEAR MR. DUCANDER: In regard to your letter of July 18, Chance Vought Aircraft, Inc., is pleased to contribute its observations and experience relative to the problems of noise and its effects.

Before commenting on those specific points which are of interest to your committee, it would be well to briefly summarize Chance Vought Aircraft's experience in this area:

This company has had to cope with the usual noise problems encountered by most aircraft manufacturers responsible for the building and test flying of high-speed jet aircraft.

We have had some complaints from the surrounding community; however, the measures we have taken to date appear to have eliminated this as a current major problem.

We have done only that amount of effort required to resolve our local situation and have not had a requirement to do additional research of greater noise parameters.

The noise-suppression devices that we have installed at this facility have cost approximately $250,000 to date and were primarily made to reduce the noise impact on the adjacent community. Ground workers working close to the aircraft have received minor benefits from these installations but are still required to use earplugs and specially designed ear coverings.

Keeping in mind our scope of effort as indicated above, we submit the following comments in answer to your specific areas of interest:

1. We have not had the necessity to expend appreciable funds in research, development, test, and evaluation in the area of noise suppression. We have been able to mollify the community by acquiring proven items of equipment that were specifically designed for our own airplanes.

2. Our organization, presently, does not have a need for an established noise and acoustical laboratory. Much of this work in the past has been done by our safety engineers with existing equipment.

3. We have not had any need to retain consultants in the field of noise and bioacoustics.

4. Our participation in the noise problem has been of a local nature and has not required us to deal with and evaluate the noise parameters as set forth by the FAA. Our estimate of an acceptable noise parameter is that decibel output that does not precipitate complaints from our personnel and the community.

5. In regard to the noise problems associated with the design of a supersonic transport covering such items as sonic boom, sonic structural fatigue, etc., we, as an aircraft manufacturer, are of course qualified to discuss these areas with an amount of technical knowledge. However, it would appear that the information we have at our disposal may not be as comprehensive as that of manufacturers who are specifically involved in the building and flight testing of supersonic transport aircraft.

6. Although we admit we have not been in a position to evaluate the overall noise picture, we have not been able to observe any impressive indication of a

coordinated program both in Government and in private industry that is oriented to solve the noise problem.

7. In regard to the question of whether the problem is receiving overemphasis, we find that the community seems to have recovered from the initial impact and is adjusting itself to accepting a higher noise level. However, we are just getting by in this marginal area, and the next generation of greater noise-producing equipment will shift this attitude of acceptance into a condition of violent objection by both communities and personnel working directly with the problem unless the state of the art advances faster than it appears to be doing at the present time.

8. It appears that aside from the obvious problem of personnel and community response to the noise associated with the static testing and flight testing of large rockets and missiles, the tremendous vibration and frequencies being generated are going to make the successful operation of our delicate supporting instruments and equipment more complex and expensive. It appears that some success in noise reduction would reduce the cost of overdeveloping supporting systems.

9. We have no requirements at this time for full-time effort of studying the psychological and physiological problems of personnel who work in a noise environment around jet aircraft, rockets, and guided missiles. Our medical people have been advising us of the danger of the problem and have been periodically checking personnel reaction. When our company becomes involved in noise parameters above those we are operating in at the present time, it may become necessary to expand our efforts in this area.

10. We have not had enough contact with NASA's program relative to noise studies to comment on their degree of effort being expended to reduce the problem.

11. Although we have had numerous complaints and threats of legal action relative to the noise we have been generating on our facility, we have been confronted with only two lawsuits to date, which as yet have not gone to court. One deals with the general noise in the area, and the other is a complaint on a sonic boom disturbance.

We hope that this information will be of some help in your effort to compile a report on this overall subject. If we can be of any further assistance, please do not hesitate to contact us.

Respectfully,

D. G. GILMORE
(For W. P. Thayer, Vice President-General Manager).

AEROJET-GENERAL CORP.,
Azusa, Calif., August 9, 1960.

MR. CHARLES F. DUCANDER,
Executive Director and Chief Counsel,
Committee on Science and Astronautics,
House of Representatives, Washington, D.C.

DEAR MR. DUCANDER: We are very pleased to have the opportunity to be of assistance to you in your investigation of the problems of noise and its effects on men and machines, referred to in your letter of July 18, 1960. Before proceeding to answer the specific questions contained in your letter, I believe a discussion of our areas of experience and general philosophy with regard to the problem you are investigating is in order. I think this will make our answers to your questions more understandable.

As you are probably aware, we have not been greatly involved in the design, construction, and operation of manned aircraft, but have concentrated our efforts primarily in the rocket and missile field. Therefore, we cannot comment authoritatively on questions relating largely to manned aircraft. In the rocket and missile field we have not had a serious noise problem from an operations standpoint. Other safety considerations such as the dangers of explosion, structural failure, and toxicity of some propellants have made it necessary to operate our engines on test stands far enough removed from our other operations that noise has not been a problem for these other operations. For these same safety reasons, operating personnel for the test stands themselves are required to be in a concrete blockhouse which automatically gives them noise protection. The remote location of our test stands has also resulted in our having no serious noise problem with the general populace. The short duration of a typical rocket run (several minutes maximum) has eased our noise problem. Flight test operations have

been conducted from Government bases which are remotely located for the aforementioned safety reasons and security requirements. No restrictions have been placed on our operations at these flight test centers because of noise.

It has been necessary, in the design of missile components and ground equipment, to give consideration to the acoustical environment in which the equipment will operate. To date this has not been a major problem, however. With the larger rocket motors of the future, we anticipate that these structural problems will become somewhat more severe.

With the foregoing as background, the following are our answers to your specific questions:

1. We have expended approximately $360,000 on research, development, test, and evaluation in the area of noise suppression for aircraft, rockets, and missiles. This work has resulted in a determination of safe, unsheltered distance for personnel when large rocket motors are being operated, as well as evaluation of acoustical fatigue effects on rocket components, acoustical test criteria for missile and ground support equipment, and development of noise suppression devices for jet engines.
2. Yes. At our Sacramento facility, tests are conducted to determine the acoustical fields generated by large rocket engines, and analyzed in a laboratory containing approximately one hundred and twenty-five thousand dollars' worth of acoustical analysis equipment.
3. We have hired consultants in the field of noise and bioacoustics on an intermittent basis. Dr. Paul Veneklasen was retained as an acoustic consultant during the period 1951 through 1956. The Bolt Berenak & Newman Co. has been retained by Space Technology Laboratory to conduct tests on the Titan II system, and will begin tests at Sacramento in the fall of 1960.
4. We cannot comment on the adequacy of the acceptable noise parameters as set forth by the FAA since we have little experience in the area of activity regulated by the FAA.
5. Again, we cannot comment on the noise problems associated with the design of a supersonic transport since we have no experience in this field.
6. While we have not been greatly involved in many of the areas, we do feel that there is a coordinated program to solve the noise problem both in Government and in private industry.
7. We do not feel that the problem is being overemphasized.
8. Our introductory discussion should explain the noise problems associated with static and flight testing of large rockets and missiles.
9. As pointed out in our earlier remarks, we have studied the psychological and physiological problems of personnel who work in a noise environment only for our own particular field of rocket testing.
10. We do feel that NASA is devoting sufficient effort in the area of noise studies to solve our problems.
11. We have been confronted with legal problems resulting from noise generation associated with our development efforts only to a minor extent.

If we can be of further assistance to you in this matter, do not hesitate to call upon us.

Sincerely yours,

DAN A. KIMBALL, *President.*

GENERAL ELECTRIC CO.,
Cincinnati, Ohio, August 10, 1960.

Mr. CHARLES F. DUCANDER,
Executive Director and Chief Counsel,
Committee on Science and Astronautics,
House of Representatives, Washington, D.C.

DEAR MR. DUCANDER: In Mr. Montgomery's extended absence from the office, your letter of July 18 has been referred to me for reply. The subject of noise and its associated problems are of particular interest to the Flight Propulsion Division of General Electric and we welcome the opportunity of supplying information and comments on this subject.

The flight propulsion division has been actively working on the subject of jet engine noise and its suppression since early in the development of the jet engine in the United States. Not long after work was started on the manufacture of jet engines, in the early 1940's, it became apparent that a neighborhood noise problem existed in areas adjacent to the factory test sites. Alleviation of this problem required the expenditure of considerable time and effort, as well as funds, con-

centrated primarily on the acoustic treatment of test cell exhaust stacks, in order that the development and acceptance testing of Air Force engines could be conducted on an expeditious basis. In the course of time, considerable data has been accumulated by portable noise equipment in an attempt to correlate noise level with community reaction. We realize, of course, that noise generation can give rise to a variety of legal problems. However, as a result of our noise monitoring procedures, acoustical treatment of engine test facilities and the remote location of our outdoor engine test site, we do not believe that the effectiveness of our development efforts has been impaired.

The division has been actively working on engine noise as installed in jet aircraft since 1956. Several programs have been conducted on a basic research level for the Air Force and the Navy. In addition, as the CJ–805–3 engine was developed for commercial use, a noise suppressor became a firm requirement. General Electric accepted the responsibility for this component and developed an effective suppressor for use with the CJ–805–3 and CJ–805–3B engines on the Convair 880 Jetliner. On a later commercial engine, the CJ–805–23 turbofan, in spite of its low noise level, additional effort has been undertaken. The overall task has covered basic research, model tests, development testing at a remote outdoor test site, and checking the final designs by flight testing at the General Electric Flight Test Center at Edwards Air Force Base. The approach taken in the rocket engine static test program has been primarily one of isolation.

The flight propulsion division has in being an acoustic laboratory suitable for research and model testing. This laboratory includes facilities for free jet tests under reverberant or anechoic conditions. Reverberant tests are used to determine sound power generation, while anechoic tests are used to determine noise propogation patterns. This laboratory is adequately staffed by competent acoustic experts and has been in operation since early 1957. This basic work has been closely allied with development testings of full-scale components on actual engines. Testing at the General Electric outdoor test facility has been extensive and considerable data on propogation patterns and intensities has been obtained with various configurations.

In addition, the General Engineering Laboratory at Schenectady has not only additional skilled technical consultants, but also an outdoor facility in operation with a rotating microphone boom which enables data, from a heated 4-inch jet, to be recorded rapidly. The General Engineering Laboratory is thus able to supply us with consultation, as well as work on specific problems.

With the degree of talent available inside the company, use of outside consultant firms has been limited. At present, the flight propulsion division does not retain any outside acoustic consultant.

It is not possible to comment accurately on the adequacy of the acceptable noise parameters as set forth by the FAA, as these parameters do not directly affect engine manufacturers. Indirectly, of course, the whole industry is affected and the adequacy of the FAA's operational control procedures will probably not be known until after a summer of operation.

In any case, the severity of any operating rule can only be mitigated through the improvement of engine noise level and aircraft performance. It is hoped that as improvements in these areas are made which will lower the community noise level, corresponding relaxation of operating rules will follow.

There is a definite need for an industrywide standard of measurement. At the present time, acceptability is judged by sound pressure level in db's or phons or perceived noise level in PNdb's. This is further compounded by the fact that even within these systems, different groups use different methods of taking data and calculating results. It is suggested that an unbiased study by an independent group not connected with the engine, the airframe, airport management, airlines, or governmental regulatory departments be used to establish a criteria for measurement of aircraft noise.

The sonic boom associated with supersonic flight is a completely different problem. An engine manufacturer has no direct control over all parameters that control sonic boom. However, it is generally agreed that transonic penetration at a high altitude will attenuate the boom to acceptable levels on the ground. Transonic penetration at high altitude requires a high thrust to drag margin that we believe can best be provided by a turbofan engine utilizing low temperature fan duct reheat. The excess thrust required for the high altitude transonic penetration would be obtained by reheating the fan air to a slightly higher temperature than is used for takeoff or cruise.

This same type of engine provides the lowest noise level for a given amount of thrust under takeoff conditions. The sound energy emanating from an engine varies approximately as the eighth power of its exhaust velocity. Taking energy

from the engine exhaust stream to run the fan lowers the velocity of the primary exhaust stream. The velocity of the fan stream so generated is increased by low temperature reheat to equal that of the primary stream to provide the high takeoff thrust required for good aircraft takeoff characteristics.

This provides the ideal from a noise standpoint, as equal stream velocities provide the lowest noise level for a given amount of airflow and thrust, and high thrust provides the good takeoff characteristics that mean low community noise after takeoff due to the rapid climb possible. As a comparison, the noise level of an afterburning turbojet of the same thrust would be equivalent to that produced by 16 reheat turbofans and by 4 dry turbojet engines.

The question of whether the problem is receiving overemphasis is not capable of being answered by a single statement. Certainly some areas of the industry are giving it tremendous emphasis, others seem to be less concerned. Generally speaking, it appears that the longer range planning could be intensified. One of the advanced developments which can be readily foreseen in the way of air transportation systems of the late 1960's or early 1970's, is the vertical takeoff and landing aircraft. In fact, General Electric is actively engaged in developing and has on test propulsion systems of the type suitable for such an aircraft. It will be commercially feasible to have high speed transports of the VTOL type capable of operating from city-center to city-center and thus offering substantial time saving to the traveler. The extent to which such methods and systems come into use will depend to a large degree upon the solution to the problems associated with the community acceptance of the noise characteristics of these vehicles.

In addition to propulsion system research and analysis, it might be appropriate to investigate steps which could be taken by potential city-center terminal sites in planning for these new transportation systems. Realistic and forward thinking zoning practices and integration of air and surface travel centers as well as continued support of noise research programs, are fields in which studies could prove fruitful.

In the past, the National Aeronautics and Space Administration has made significant contributions to the field of noise suppression and basic understanding on noise phenomena. The results of their research and effort have provided a sound basis upon which the current noise suppressors have been founded. This has enabled the present commercial air transport systems to operate with considerable reduction in the number of problems due to noise. However, the reorientation of the NASA toward space systems in the past years has resulted in a drastic reduction in basic aerodynamic effort and a virtual elimination of research and effort applicable to aircraft noise problems. It appears reasonable to give serious consideration to redefining of the role of the NASA in terms of aircraft systems and to increasing the attention and effort which they apply to associated basic problems. Reactivating the effort on aircraft noise to a reasonable level should be part of this consideration.

I sincerely hope these comments will prove of value to the Committee on Science and Astronautics. The General Electric Co. is glad to have been of service.

Sincerely,

D. COCHRAN,
General Manager,
Flight Propulsion Laboratory Department.

LOCKHEED AIRCRAFT CORP.,
Burbank, Calif., August 10, 1960.

Mr. CHARLES F. DUCANDER,
Executive Director and Chief Counsel, Committee on Science and Astronautics, House of Representatives, Washington, D.C.

DEAR MR. DUCANDER: Following are the comments of our engineering and scientific staff concerning the specific points listed in your letter of July 18 relative to the hearings on the problems of noise and its effects on men and machines.

1. In the past 5 years we have expended in excess of $2 million worth of effort in acoustic research and testing. Effort has been applied to noise control and suppression for comfort within the aircraft and on jet and external aerodynamic noise suppression.

2. Our research laboratories include an acoustic research facility complete with anechoic chamber, recording equipment, and psychoacoustic test equipment.

3. Presently we do not retain consultants in the field of noise and bioacoustics, but we are considering obtaining the consulting services of bioacoustics and psychoacoustic specialists from a nearby university.

4. We have no comment on the adequacy of the acceptable noise parameters as set forth by the FAA.

5. The noise problems associated with the design of a supersonic transport are discussed by Hibbard and Bailey in a paper entitled "The Case for the Supersonic Transport" which was presented at the 1959 summer meeting of the Institute of the Aeronautical Sciences. A copy of this paper is attached. Sonic boom is mentioned on pages 16 and 17, sonic structural fatigue on pages 5 and 6, and engine noise on pages 14, 15, and 16.

6. We do not feel that there is a coordinated program in Government and in private industry which is oriented to solve the noise problem.

7. We do not feel that the problem is receiving overemphasis.

8. At present the frequency, duration, and location of static testing of large rockets and missiles are such that adverse public reaction has not been forthcoming. Larger size rockets or increases in frequency or duration might result in unfavorable reaction.

9. One of our scientists is presently engaged in a psychoacoustic research program. All personnel working in high-noise-level areas are checked periodically for any deficiencies in audio response.

10. We do not feel that the National Aeronautics and Space Administration is devoting sufficient effort in the area of noise studies which would lead to a solution of our problems.

11. No legal problems have arisen because of Lockheed's development programs. However, a production program caused legal action by a group of residents in the vicinity of a jet trainer production flight facility. Periodically, complaints have been received from residents in the neighborhood of Lockheed flight operations but no other legal action has been taken.

I hope that this information will assist you in your work. If you wish further or more detailed data, please feel free to call upon us.

Sincerely yours,

COURTLAND S. GROSS, *President.*

CENTRAL INSTITUTE FOR THE DEAF,
St. Louis, Mo., August 12, 1960.

Capt. HOWARD J. SILBERSTEIN,
Staff Consultant, Committee on Science and Astronautics,
House of Representatives, Washington, D.C.

DEAR CAPTAIN SILBERSTEIN: Enclosed please find the statements you requested of Dr. Hallowell Davis in your letter of July 15, 1960. I believe it is largely self-explanatory, but if you have any questions I will be glad to try to answer them. As noted in the statements, Dr. Davis left on his vacation after completing the first draft and asked me to edit the material.

Sincerely yours,

DONALD H. ELDREDGE, M.D.

CENTRAL INSTITUTE FOR THE DEAF,
St. Louis, Mo., August 11, 1960.

Capt. HOWARD J. SILBERSTEIN,
Staff Consultant, Committee on Science and Astronautics,
House of Representatives, Washington, D.C.

DEAR CAPTAIN SILBERSTEIN: I have given considerable thought to your letter of July 15 and to the problems which you indicate would be of interest to the Committee on Science and Astronautics. I submit herewith a few comments on those points on which I feel competent to speak, and I hope that they may be useful in connection with the hearings that are scheduled to begin on August 16, 1960.

No. 3. The Work of the CHABA Committee.

When I retired in 1959 as Executive Secretary of CHABA I prepared a historical statement and an evaluation of the work of the CHABA Committee in the past and the nature of its problems in the future. This statement I presented at the annual CHABA meeting in October, 1959 and it is my understanding that it was to be published in full or in part as a CHABA report. You may already have

available a copy from the present executive secretary, Dr. Milton Whitcomb. The most pertinent parts of this statement are the original and present definitions of the areas of CHABA interest and then the entire second half of the presentation, comprising the subheadings "The CHABA Job," "CHABA Contributions," and "The General Problem of Noise." I call attention particularly to that final section.

In case you do not have the text of this statement available I attach a copy of the final section herewith as appendix A.

No. 7. Noise problems associated with Navy carrier operations.

No. 9. Psychological and physiological problems of personnel who work in high-intensity noise.

My direct experience in this area is derived from the BENOX project, including studies at the Naval Air Test Center at Patuxent and aboard U.S.S. *Coral Sea* (1953),[1] and from the project entitled "Auditory and the Non-Auditory Effects of High Intensity Noise" (ANEHIN) conducted jointly by the Central Institute for the Deaf, St. Louis, and the U.S. Naval School of Aviation Medicine Pensacola.

An evaluation of the problem of high-intensity noise and military operations, based on the BENOX report, was issued as CHABA Report No. 1 (1954).[2] I believe that this evaluation is still valid. The final report of project ANEHIN was issued as joint project NM 13 01 99 subtask 1, report No. 7, Pensacola, Fla.: Central Institute for the Deaf and Naval School of Aviation Medicine. The ANEHIN report was summarized in an article entitled "Effects of High Intensity Noise on Naval Personnel" that appeared in the U.S. Armed Forces Medical Journal in 1958 (vol. IX, No. 7, pp. 1027–1048). That article expresses very well my present views on the psychological and physiological problems of personnel who work on the flight deck of naval aircraft carriers. I call attention to the following concluding paragraphs:

"No clear, positive effects, either auditory or nonauditory, of exposure to noise were shown by any of our tests. Certain small positive effects were found by the audiometric and the psychiatric studies, but these are attributed to causes other than jet-engine noise. A suggestive trend toward a slight general decrement in performance did appear in the psychologic tests of jet-plane maintenance personnel.

"CONCLUSIONS

"As of March 1957, there was no reasonable cause for immediate alarm concerning cumulative aftereffects of jet-engine noise exposures of naval personnel.

"It is unsafe to extrapolate from present noise exposures to the more severe exposures that must be anticipated in the future. The extent of the present margin of safety is not known, and continued vigilance is required.

"In the opinion of the ANEHIN group, at least two other undesired effects of high-intensity noise were, as of 1957, more serious threats to military operations than were its cumulative aftereffects. They were (1) interference with communications, and (2) decrement in performance of personnel during actual exposure to high-intensity noise.

"RECOMMENDATIONS

"Further field studies of this sort are not necessary until there is a considerable increase in operational noise exposures. Meanwhile, monitoring of noise exposures with the equipment developed by ANEHIN should be instituted to detect such changes.

"Monitoring audiometry and also monitoring by selected psychologic and psychomotor tests should be instituted for the protection of personnel who suffer the most severe noise exposures.

"Valid criteria of hazardous noise exposures should be established by carefully controlled experiments with human volunteers, using careful measurements of noise exposure and the tests of the ANEHIN battery. In such experiments the decrement of performance during actual exposure to noise also should be measured."

I wish to emphasize the importance of the concept of monitoring, both in respect to effects on hearing and with respect to any other detrimental effects. It has been my impression that the conclusion that "as of March 1957, there is no cause for immediate alarm" and that "further field studies are not necessary

[1] BENOX Report: "An Exploratory Study of the Biological Effects of Noise," contract N6 ori-020 task order 44, ONR project NR 144079, the University of Chicago, Dec. 1, 1953.

[2] "High Intensity Noise and Military Operations: An Evaluation," CHABA Report No. 1, project NR 140-069, contract NONR-1151 (01), Jan. 25, 1954.

until there is a considerable increase in operation noise exposures" have been accepted without sufficient attention to the qualification that monitoring of hearing and monitoring by selected psychologic and psychomotor tests should be instituted for the personnel who suffer the most severe noise exposures.

The seriousness of the stress imposed by high-intensity noise is very difficult to evaluate. In a stressful situation any additional stress increases the probability of human failure or error. On the other hand, proper indoctrination and adaptation, combined with judicious selection of personnel, considerably reduce the hazards of the stresses. Furthermore, the effects on performance of environmental stress can be overcome to a considerable but uncertain extent by increased motivation. Where the chances of success of a mission are marginal, the stress of high intensity noise might well become critical, but it is impossible to specify in advance exactly when and where such failures will begin to occur. High-intensity noise has probably already been a contributing factor to a number of human failures in military operations.

Quite apart from psychological and physiological problems, the interference with speech communication by high intensity noise should not be overlooked or minimized. This is probably the most serious of the noise problems associated with present Navy carrier operations. For the present psychological and physiological problems appear to be minimal if proper use is made of available personal protective equipment such as ear plugs and ear muffs. But, coordination of the activities on many men in a very noisy environment is required for the complex operations of an aircraft carrier. Although a variety of visually displayed signals are usefully employed, the greater flexibility of speech communication is required for optimum coordination. More widespread use and possibly further development of communications equipment designed for use in high-intensity noise, such as the equipment developed at the Navy Electronics Laboratory, should be accelerated.

No. 8. Bioacoustic problems of rockets, missiles, and space travel.

In case the material is not already available to you, I call attention to the memorandum dated June 26, 1959 prepared by D. H. Eldredge and H. Davis (the CHABA secretariat at that time) and addressed to CHABA Working Group No. 33. This material was prepared, primarily by Dr. Eldredge, in the expectation that it would form the basis of a working group report. The report in question may or may not have been completed. The memorandum in question is essentially a summary of the working group presentation at the CHABA meeting in October 1958, and a copy can be presumably obtained from Dr. Whitcomb.

In the covering letter that accompanied the memorandum we wrote:

"At the CHABA meeting it was apparent that the bioacoustic problems posed by rockets, missiles, and space travel were not radically different from many current problems. There were no indications for new research aimed at finding new principles, etc. This consensus seemed to detract from the fact that important practical problems in noise control remained and must be faced if successful space travel is to be achieved. We have tried to emphasize this point in the report."

The conclusions and recommendations in the memorandum were as follows:

I. Noise problems of major significance to the success of manned space travel will be encountered during all phases of the mission. The precise magnitudes of the problems are not known. Reasonable estimates of the magnitudes of the problems indicate that all of the problems can be solved if present-day knowledge of acoustical engineering is applied to the design and layout of a space vehicle and its contents.

A. Exposures to maximum noise levels will be during the launch and reentry phases of the mission.

1. The exposure durng the launch phase will be brief, about 2 minutes.

2. The duration of the exposures to high-noise levels of the reentry phase will be largely determined by the reentry maneuvers used.

3. Noise control measures designed to preserve criterion noise levels during the launch phase are likely to be adequate for the reentry phase regardless of the maneuver used.

B. During the cruise phases of a mission the noises produced by pressure systems, ventilators, secondary power, etc., within the cabin of the spacecraft can reach levels that will seriously hinder speech communication and may, during long cruises, seriously impair hearing.

1. The ability to use speech communication is considered a prerequisite to the maintenance of intelligent, coordinated, and effective behavior in space travelers.

2. The noise levels can be kept low enough to allow speech communication if several commonsense measures are observed.

(*a*) Internal machinery can be designed and selected to achieve the lowest sound power levels in the speech frequency range that are consistent with other operational requirements.

(*b*) Reduction of noise at the pilot's ear and microphone as well as the primary functions of the equipment can be considered in the placement of the noisier machines within the cabin.

(*c*) Standard measures for the control of noise are also available to supplement measures (*a*) and (*b*).

II. Vibration problems of vital significance may be encountered during launch and reentry phases of a space mission.

A. Some information about man's tolerance for vibration and acceleration is available.

1. Less is known of the amount man's tolerance can be increased by protective personal equipment.

2. Also, less is known of man's ability to perform tasks during vibration and acceleration.

III. Noise in areas adjacent to the launch site also presents problems that will require action.

A. Sound pressure levels of approximately 145 decibels per octave band at a distance of 100 feet will exist.

1. Launch personnel and near neighbors will require some protection.

2. Launch from the confined spaces of ships and submarines will introduce special problems.

B. The unusually high levels of very-low-frequency sound energy (frequencies below 75 c.p.s.) will be considered objectionable by observers at distances up to 5 miles.

C. Under average weather conditions a speech interference level of 60 decibels will be exceeded at a distance of 5 miles.

D. The duration of the maximum sound pressure levels will be brief and conventional control measures should be adequate.

IV. Incapacitating vertigo as a consequence of the rotational, linear, and vibratory accelerations acting on the vestibular system was recognized as a serious problem. The working group chose not to consider this problem but believes the problem merits special attention.

RECOMMENDATIONS

I. Specifications for the maximum sound pressure levels to be allowed at the pilot's head in a space vehicle should be furnished the manufacturers of the vehicles. These specifications should be written to guarantee satisfactory speech communication at all times.

A. The specifications can be less demanding during the brief periods of launch and reentry than during the longer periods of cruise.

II. Studies to determine man's tolerance for and performance during low-frequency vibrations and transient accelerations when supported by personal protective equipment should be continued with high priority.

III. Specifications for maximum vibrations and accelerations based on the studies recommended under II should be supplied to the agencies responsible for the design of space vehicles as soon as possible.

IV. Sites for launching of rockets, missiles, and space vehicles should be chosen carefully with regard to the wide spread of high-level noise that accompanies these operations.

No. 4. Sonic boom and the noise problems of airports.

The problem of the annoyance of nonparticipating populations in the general vicinity of airports, missile test areas, or areas that may be affected by sonic booms is intricate and difficult. It is discussed briefly in the historical summary of CHABA activities noted above. The stress which is posed by noise in this case is essentially one of annoyance, with perhaps an added element of fear and occasional bits of objective physical damage such as broken windows or outright interference with business activities such as conferences and telephone conversations. The evaluation of such annoyance, and even more the prediction of what the reaction of an individual or a group of individuals to such annoyance will be, is an almost impossible task, yet the political and economical importance of such individual and group reactions is great and undeniable. Efforts to study this problem with anything approaching scientific rigor will be expensive and the results may be controversial. In my opinion, however, it is important that such studies should be initiated, continued,, or resumed. Such studies may help to

develop the necessary criteria for permissable noise generated by aircraft, missiles, etc.

Considerations of sonic boom and community tolerance for this and other noise of aircraft will have an important bearing on the future development of supersonic transport. It seems inevitable that community tolerance will impose severe operational and geographic limits on such activities. The future development of supersonic transport clearly involves community planning and perhaps even legislative and legal definition of the rights and principles that are involved in the conflict of interests.

No.'s 5 and 6. The support of the study of noise problems.

On the whole the research effort of all three of the medical departments of the Armed Forces has shown commendable ability to stay ahead of the noise problems in the services. For example, the results of the ANEHIN project support this conclusion. Also the Air Force program for the study of noise and vibration control has been broadly conceived, has provided much of the necessary factual data, and should continue to be most valuable. I am not aware of any duplication of effort in this area. The opportunity provided by the Committee on Hearing and Bio-Acoustics (CHABA) for the exchange of information and ideas among scientists from Armed Forces and civilian laboratories has, I believe, helped to prevent unnecessary duplication of effort and has helped each scientist to know better how his work fits into a larger pattern. CHABA should certainly be continued because I believe CHABA should continue to be an important clearinghouse for information and ideas concerning noise problems of all sorts, particularly those of military impact.

However, my general experience of the past 10 years has been that inadequate attention and support has been given to certain long-range research projects which may provide fundamental information on the effects of noise on man and man's reactions to noise. The study of community reactions to aircraft noise is one example. The study of human psychomotor performance in the presence of high intensity noise that is comparable to the noise encountered on the flight deck of carriers or in the vicinity of rocket launchers is another. Systematic monitoring both of the hearing and of psychomotor performance of individuals who work habitually in high intensity noise is a third.

Another problem, which is not so much a matter of obtaining information as of using and applying effectively information that already exists is how to incorporate at the planning and design state of aircraft, missiles, carriers, and airports, the problems of noise and vibration, in relation both to structural and to human factors. In order to avoid serious risks or difficulties in performance it may be necessary to accept certain limitations in design or penalties in regard to weight, space, or cost. But these penalties are far less if the problem is considered early as part of the original specifications of the task. In part the problem of applying existing information exists because the channels of communication from the medical departments to the prime contractors and to those who write procurement specifications are difficult or absent. In part this problem also exists because the medical departments do not have definitive answers to all the questions that should be asked by the writers of specifications. Many answers must still be hedged with qualifications. In order to write such specifications realistically and accurately we require better criteria for permissable noise levels and noise exposures than are now available. The improvement of criteria is thus a long-range and, perhaps, rather expensive type of research which should be carried out but which is likely to be overlooked or inadequately supported.

Hoping that these opinions and the supporting material may be of use to you I am,

Sincerely yours,

DONALD H. ELDREDGE
(For HALLOWELL DAVIS, M.D.).

Dictated by H. Davis.
Edited by D. H. Eldredge, M.D.

APPENDIX A. THE GENERAL PROBLEM OF NOISE

The chart of CHABA working groups looks ominous with only four new ones in the last 2 years. I believe, however, that there will always be a need for CHABA and business for CHABA because none of its major problems will ever really be solved. If they do appear to be solved it will be only indirectly because of changes in the technology of warfare, political decisions or social developments. I say this because the major CHABA problems are problems of human tolerance for noise and noise is here to stay.

The CHABA problems differ from one another chiefly in the nature of the stress that noise imposes. It may be direct bodily injury, it may be impairment of hearing, it may be interference with psychomotor performance or with speech communication, or it may be simply annoyance.

The problem is to balance the cost of prevention or cure against the risks, difficulties, or annoyance. This is a difficult balance to estimate as it is hard to find a common denominator. The most obvious common denominator is the economic cost in dollars, as when veteran's compensation for hearing loss is compared to the cost of noise control and hearing conservation, but elsewhere we must deal also with very different considerations such as the success of military operations or possible undesired legislative controls.

In any case the balance is dynamic and it may be upset by new factors. Such a new factor may be a technological advance such as jet propulsion. This is actually what created the military noise crisis of 1952 that led to the establishment of CHABA. Or it may be political and judicial decisions such as the enactment and the interpretation of workmen's compensation laws. These laws and decisions created the industrial noise crisis just a few years earlier. Or it may be a sociological change or pressure, such as the universal growth of cities and the tendency of their suburbs to surround airports. The point is that any upset in the balance means either a CHABA crisis or a CHABA problem solved. Usually the stress or the expense is increased, and there is a new noise crisis.

The major CHABA problems each involve a balance between noise making and some undesired effect of the noise on man. Technological advance or sociological developments are upsetting the old balances. There is actually a common general pattern which CHABA has found empirically in dealing with one problem after another. In general terms and as a pattern for the future, here are the steps:

(1) Clear away the fog of mystery and fear and emotion that surrounds any novel physical stress, whether it be radio waves, ultraviolet light, electron beams, alpha particles, ultrasonics or high intensity noise. The surest way is through objective tests and clear exposition at the popular level. Quantitative measurement helps greatly, but even in advance of precise measurement direct qualitative demonstrations may hold the line.

(2) Find ways to measure both the stress and the effect. The concepts of noise exposure (with its emphasis on time factors as well as on intensity and spectrum), of speech interference level and of hearing impairment illustrate such ways of measuring. This step is in the CHABA area, and it is a big step.

(3) Find the relation between stress and effect. The relations of hearing loss to noise exposure is a familiar example. The relations will never be precise because of the many variables that are involved, including biological variability. Others are literally as fickle as the weather. At least, however, statistical relations can be established. This step also is in the CHABA area, and is probably the most difficult step of all.

(4) Establish criteria for the stress even if they must be crude interim criteria. This is not entirely a technical CHABA affair because certain broader decisions must be made as to the degree of risk, of extra cost or effort, or of annoyance that is acceptable. It is interesting that international standard curves are being proposed for use in establishing criteria for noise exposure, for speech interference and for annoyance. CHABA can participate in formulating criteria.

(5) Establish systems of monitoring in order to detect and deal with either—

(*a*) an unexpected increase in the amount of stress imposed on individuals, or

(*b*) an unacceptable amount of injury, annoyance, etc., such as should require a modification of criteria, or

(*c*) the cases of individual injury, such as hearing loss, that must be expected on a statistical basis with any reasonable criterion levels. With careful monitoring they are detected early before impairment is severe. Many techniques of monitoring are in the CHABA area, although the choice of the "monitoring levels" that indicate the necessity for action involves broader decisions. The measurements used in monitoring may be strictly acoustic, such as those for noise exposure, speech interference level, and perhaps annoyance levels. They may be psychoacoustic, as for hearing level or threshold shift, or they may be strictly medical, psychiatric, or sociological. The latter are outside the CHABA area.

(6) Evaluate the technical feasibility and economic costs of noise control and/or of personal protection. It may be of considerable importance to know in advance the theoretical limits of noise suppression of jets, of ear protection, of sound isolation, etc.

(7) Improve and validate criteria continually on the basis of planned experiments and of the experience gained by careful monitoring. Here is the great continuing CHABA task.

(8) Establish acoustic requirements for acceptability of machines and vehicles of all sorts. This again is only partly a CHABA problem, but it is well known that economic costs can be reduced greatly if acoustic requirements exist and are considered early in design and planning. This principle extends to the planning of airports, truck routes, etc.

(9) Keep the balance between noise and its effects on man in equilibrium by careful monitoring and hope that the problems will be alleviated by new technical advances. This may often happen even before criteria that are scientifically based and validated can be evolved.

All of these steps constitute what we mean by "learning to live with a problem." Modern civilization has many such problems, and noise is one of them. We can perhaps take some comfort in the thought that familiarity breeds acceptance as well as contempt. A favorable emotional attitude toward a stress and particularly toward an annoyance makes as much difference as many decibels of noise control. Social attitudes and social values develop and can often be molded, particularly by making people aware of just what the opposing interests are and where the costs fall. But the basis for persuasion must be knowledge and the basis for knowledge is measurement. CHABA is concerned with knowledge and with measurement.

DOUGLAS AIRCRAFT CO.,
Santa Monica, Calif., August 12, 1960.

Mr. CHARLES F. DUCANDER,
Executive Director and Chief Counsel,
Committee on Science and Astronautics,
House of Representatives, Washington, D.C.

DEAR MR. DUCANDER: In response to your invitation of July 18, I am pleased to enclose with this letter a résumé of the Douglas Aircraft Co.'s position with respect to the specific questions proposed to us on various aspects of the aircraft and rocket noise problem. Certain company technical reports bearing on this timely and important subject also are enclosed.

This company, as a manufacturer of jet aircraft and rocket-powered missiles, has long been cognizant of noise problems associated with advancements in our field of activity. Since it has always been our policy to work closely with other private organizations and with public agencies in programs directed toward alleviating undesirable corollaries of our business, we are especially pleased to offer the committee this summary of our views. We trust the comments and associated reports will prove helpful to the inquiry.

You may be sure that we remain ready to offer any further information or assistance within our province.

Sincerely,

DONALD W. DOUGLAS, Jr.

1. An estimate of the dollar effort you have invested in research, development, test, and evaluation in the area of noise suppression in your aircraft, rocket, and missile development.

Douglas constructed an acoustical laboratory 5 years ago at a cost of over $350,000. Salaries and support for people in Douglas whose talents are applied to solving acoustical problems are on the order of $500,000 a year. The engineering costs of converting acoustical developments into designs of airplanes, missiles, and ground equipment probably involves an additional $500,000 per year. It is difficult to estimate what the total cost in tooling, manufacturing, and administrating operations of these activities would run. Estimates for the development of the in-flight noise suppressor for the DC–8 exceed $15 million.

2. Does your organization have an established noise and acoustical laboratory?

Our company does have an established acoustical laboratory which has been in existence and has been constantly improved since the days of designing the DC–3 airplane. Douglas has had a continuous staff of acoustical engineers also since the DC–3 days. In fact, Elmer Wheaton, one of our

engineering vice presidents, was one of the first two acoustical engineers at Douglas.

3. Does your organization retain consultants in the field of noise and bioacoustics, such as Bolt Beranek & Newman Co.?

Douglas retains consultants in the field of noise and bioacoustics whenever it is necessary to obtain talent not already provided in the Douglas organization. Most of our acoustical counseling is provided by individuals in the field rather than by the retention of a company like Bolt Beranek & Newman, since we do have our own engineering staff in acoustics. We work closely with Bolt Beranek & Newman and would use them in a counseling capacity when we need special talents found in their organization and not in ours.

4. Can you comment on the adequacy of the acceptable noise parameters as set forth by FAA?

FAA's noise parameters should not be construed as representing either noise standards or noise regulations. It would be very difficult, in the present state of the art, to establish uniform standards or regulations applicable to all aircraft and for all particular airport noise problems since there are large variations in both areas. FAA recognizes this fact and at the present time is depending upon coordination between engine manufacturers, aircraft manufacturers, aircraft operators, and airport operators to work out their mutual problems compatible with the individual problems of all concerned.

5. Can you discuss the noise problems associated with the design of a supersonic transport covering such things as sonic boom, sonic structural fatigue, and problems encountered with takeoff and approach noise reduction?

As reported previously to the committee, Douglas believes external sound generated by a supersonic airliner will be somewhat greater than the noise of today's jets, but the ability of the supersonic transport to climb more rapidly will tend to counterbalance the increased noise so that the effect on communities may be no greater than with present aircraft. Although the SST will create a sonic boom, its cruise altitude of 70,000 feet would dissipate the shock effect to a degree which would minimize ground effects. Because of sonic effects, however, it may be necessary to establish a mandatory operating cruise altitude over terrain rather than altitude above sea level. We conceive a supersonic transport that will climb to altitude and let down at subsonic speeds. We have pioneered in the sonic structural fatigue problem and have jointly worked with all members of the aircraft industry in alleviating problems associated with takeoff and approach noise at all airports. Most of the theoretical and experimental studies in the sonic boom problem have been made by NASA and we are guided very much by the results of their work since it appears accurate and realistic. Several reports are enclosed which show the specific work Douglas has done in the sonic structural fatigue problem. Our laboratory is equipped to perform experimental tests in sonic fatigue problems. The aircraft we have built and are building are designed to resist structural fatigue and we are including all of our past experience into the design of our missiles.

6. Do you feel that there is a coordinated program, both in Government and in private industry which is oriented to solve the noise problem?

A program oriented to solve the noise problem has not been coordinated in Government and private industry in the past as well as it might have been. However, natural pressure concerning the problem coming from both the public and those branches of Government and industry most closely associated with such public problems is resulting in better coordination all around and more sincere effort on the part of all concerned to solve those parts of the problem which fall naturally into their own areas of interest. Engine manufacturers working on the development of fan engines and the detailed design of compressor and turbine configurations are making considerable headway in reducing the noise output of jet engines. Aircraft manufacturers are studying and incorporating in their design ways of operating aircraft to minimize the noise. Aircraft operators are making use of these operating procedures and are spending considerable amounts of money provide ground noise support facilities to keep the noise created by the aircraft during maintenance operation to a minimum.

7. Do you feel that the problem is receiving overemphasis?

Certain specific approaches to reducing the problem, when conceived in anger and factual ignorance, are probably being overemphasized in some localities. We feel that with education and with the realization that industry

is not underestimating the problem these areas of overemphasis will be self-adjusting.

8. What are the serious noise problems associated with the static testing and flight testing of large rockets and missiles?

Recognizing the possibility of intruding upon community privacy, this company has established its own geographically remote locations for static testing of rocket powerplants and missiles. Flight tests are all conducted from Armed Forces installations. The serious noise problems associated with such tests are mainly concerned with protection of operating personnel and equipment from the very high sound pressure levels generated by powerful rocket engines. The noises produced by many items of support equipment present this same type of problem. Douglas studies every missile system it designs from this standpoint and care is taken that personnel are protected either by removal to safe areas, by design of enclosures and blockhouses to protect the personnel, or by individual protection devices. The capability of associated equipment, both structural and electronic, to withstand the noise field due to the missile is also studied and appropriate design and construction procedures incorporated.

9. Does your organization study the psychological and physiological problems of personnel who work in a noise environment around jet aircraft, rockets, and guided missiles?

Our organization does study the psychological and physiological problems of personnel who work in a noise environment around aircraft and missiles and recommendations for the complete protection of personnel are made to the system designers who incorporate this information in the total system design.

10. Do you feel that the National Aeronautics and Space Administration is devoting sufficient effort in the area of noise studies which would lead to the solution of your problems?

The NASA has, in the past, been very active and has made considerable contributions in the control of noise from jet engines and in the protection of people inside aircraft. Most of this work was done when the organization was known as the NACA. Since reorganization, and with more emphasis placed on space projects, the NASA's efforts in the noise field have been mostly related to sonic boom studies, studies of the noise inside the Mercury capsule, and in the maintenance of a working knowledge of noise problems in general associated with rockets and missiles. We feel that they should return to the old NACA philosophies about noise and that their efforts in the total field should be considerably expanded.

11. Have you been confronted with legal problems resulting from noise generation associated with your development efforts?

Corrective measures taken by the company have been sufficient to avoid direct or specific legal problems resulting from noise associated with development work at any of our several facilities. However, one legal action was brought against us as a result of the frequent takeoffs and landings of military jet aircraft undergoing modification by Douglas.

BOEING AIRPLANE CO.,
Seattle, Wash., August 15, 1960.

AEROSPACE INDUSTRIES ASSOCIATION,
Washington, D.C.
(Attention: O. R. Cook, President.)

GENTLEMEN: In response to your TWX, August 3, 1960, the information and views of the Boeing Airplane Co. concerning aircraft noise problems are being forwarded through your organization to present to the House Committee on Science and Astronautics.

1. The research and development costs for the sound suppressors used on Boeing models 707 and 720 series jet transports were approximately $6 million. The Company is currently expending $650,000 per year for consultation, research, and development effort in the noise fields.

2. Acoustic laboratories in Seattle, Wash., Wichita, Kans., and Morton, Pa., represent an investment of $675,000. Facilities are available for generation of sound, for measurement, recording, and analyzing. Engine test stands, model scale facilities, and flight test facilities are used to develop suppressors, evaluate engine and rocket noise. Anechoic, reverberation, and demonstration chambers

plus specialized test equipment with a laboratory staff of 56 engineers and technicians support current research and development program.

3. Boeing obtains the service of acoustic consultants for special purposes. However, since our "in house" capability in this field is extensive, a continuous retainer is not required.

Among consultants used are:

Geiger & Hamme, Ann Harbor, Mich.
Paul Veneklasen, Beverly Hills, Calif.
General Applied Science Laboratories, Westbury, N.Y.
Dr. Hans Leipmann, California Institute of Technology.
Dr. Walter Soroka, University of California.
Dr. Osman K. Mawardi, Massachusetts Institute of Technology.
Dr. D. J. Richards, University of Southampton, England.

4. The Federal Aviation Agency's rulemaking and proposals for noise abatement at various civil airports generally permit the use of procedures which Boeing has developed and recommends to its airline customers. These procedures are designed to minimize the noise in communities surrounding the airports due to transport aircraft flight operations. The Agency's recognition of safety of flight as an inviolate, primary requirement of any noise abatement procedure is consistent with its statutory responsibility.

5. The supersonic transport will have, to an as yet unpredictable degree, the noise problems associated with present day jet transports. Engine type and location will greatly influence the noise problems. The supersonic transport will benefit from noise suppression methods developed for present subsonic transports.

The sonic boom is perhaps the most significant community noise problem associated with supersonic transports. Sonic boom intensity can be minimized through control of the flight profile, i.e., through high altitude flight and avoidance of population centers. But the effectiveness of these measures may not be great enough to permit regular operation over populated land areas. Experimental data are required to determine the sonic boom intensity as a function of airplane size. It is not expected that sonic boom intensities caused by very large aircraft will vary with altitude and mach numbers in the same manner as those caused by smaller aircraft. The influence of weather conditions on the sonic boom is not completely understood.

6. Certain areas of the noise problem have had the benefit of a coordinated program. For example, the recently published FAA document "Noise Abatement Procedures" was the result of meetings which coordinated the views of airlines, pilots, jet transport manufacturers and Government. In the aircraft noise reduction area, Boeing developed suppressors for jet engines on a company financed, proprietary basis with no Government requirement. However, since the development of these suppressors, Boeing has freely shared its knowledge in this field with both Government and industry.

It is the opinion of the Boeing Airplane Co. that adequate long-range zoning around airports is the most important factor in noise reduction for the communities. The most effective noise suppressors, new engine designs, and optimum flight procedures are being offset by the construction of new housing developments in airport approach corridors. Long-range planning by local port authorities and local government is very important. The recommendations of the Doolittle Commission for airport planning have been ignored in too many instances.

7. The importance of reducing aircraft noise has been recognized by Boeing for many years. In certain areas some interests appear to thrive on publicity adverse to airlines, airports, and aircraft manufacturers. This results in emotional charges and demonstrations which indicate poor direction of public relations and information.

8. Serious problems associated with static and flight test of rockets and missiles are (1) the acoustically generated vibration of missile and ground support structure and equipment and (2) noise propagation to nearby communities. In the future, larger thrust rockets can be expected to generate more power in acoustic noise than the total mechanical power generated by present-day rockets.

9. The medical section of Boeing is studying the following problems:

(*a*) Statistical evaluation of audiometric data of personnel exposed to jet engine noise to estimate the relationship between known jet noise exposure and the amount of hearing loss it may produce.

(*b*) Evaluation of ear protectors, research in improvement of existing ear protective devices and development of improved types of personal noise protectors.

Research and establishment of personnel noise safety requirements have been carried out by the medical section for a number of years.

10. Basic research in (1) the design of compressors and inlets for turbojet engines, (2) the optimum design trades of helicopter rotor noise, and (3) more intensive collection and distribution of rocket noise survey data should be accomplished by the National Aeronautics and Space Administration. During the past several years, the major orientation of NASA efforts has been almost entirely toward space problems.

11. The Boeing Airplane Co. has received various complaints from residents of Seattle and Renton concerning noise from development and research projects. In some instances the company has compensated such persons for minor damage, but none of the noise complaints has resulted in any legal proceedings to date.

Very truly yours,

WILLIAM M. ALLEN, *President.*

CONVAIR,
San Diego, Calif., August 16, 1960.

Gen. O. R. COOK,
President, Aerospace Industries Association,
Washington, D.C.

DEAR ORVAL: We have been requested by the House Committee on Science and Astronautics to answer a number of questions and as a result of your August 3 wire, we are passing these answers on to you for coordination. The paragraphs are numbered in accordance with the numbers of the questions in Mr. Charles Ducander's letter to me dated July 15, 1960.

1. We estimate that Convair has invested $3,250,000 in capital facilities for suppression of noise in connection with research and development activities in our aircraft and missile programs. This total does not include funds expended toward the soundproofing of aircraft interiors for passenger comfort. In addition, the General Electric Co. estimates that it has spent somewhat over $2 million for development of the engine sound suppressor which is attached to the CJ–805 powerplant in our 880 jet transport. Additionally, research and development is currently being applied to sound suppression in the aft fan version (CJ–805–23) for the model 600 airplane. The extent of this investment will not be known until after the project is completed.

2. Convair has at its San Diego Division a complete acoustical laboratory which is used for the soundproofing of aircraft. Each of the four Convair manufacturing divisions also has faciilties for testing sonic structural fatigue of aircraft and missile components.

3. Since 1954, Convair has maintained a continuing consulting contract with the Bolt Berenak & Newman Co. Prior to that time, this same group of sound consultants was retained on a project basis.

4. The establishment of acceptable noise parameters is a continuing process. Acceptability is, to a large extent, dependent on local geographical situations, atmospheric conditions, and disposition of the local community as well as subjective psychological reaction of individual residents. For this reason it is anticipated that the establishment of acceptable noise parameters will remain fluid for some time and will be different for various local conditions.

5. A considerable amount of literature has been developed on the subject of supersonic transport booms. A NASA paper by D. J. Maglieri and H. W. Carlson on "The Shock-Wave Noise Problem of Supersonic Aircraft in Steady Flight" is a good engineering reference today on this subject. Certainly, supersonic aircraft will have to fly at fairly high altitudes in the order of 55,000 to 60,000 feet or higher and will have to fly at subsonic speeds below these altitudes in inhabited areas.

The physics of sonic structural fatigue is extremely complex, both in terms of noise generation and the effects within the structure itself. A great deal of information, including test data, has been produced in the development of our B–58 supersonic bomber. Certainly, it is necessary to design for the sonic vibration environment of structures if we expect the structures to stand up from a fatigue standpoint.

6. Yes; we feel there is good coordination in both Government and private industry directed toward solution of aircraft noise problems.

7. In general, we feel that this problem is not being overemphasized. However, in some instances where the problem is misunderstood, some of the elements of the problem have been distorted.

8. The static test and flight test of large rockets and missiles is necessarily accompanied by tremendous output of propulsive power. At the present time there is no indication of any means whereby the noise generated by this power can be effectively suppressed toward reducing the exposure of operating personnel or the public at large. The only practical solution, which is the present one, is to maintain wide separation distances between personnel and the rocket motors during operation.

9. Beyond maintaining acceptable standards of industrial protection, our organization has conducted no special studies of psychological and physiological problems for personnel who work in a noise environment.

10. From our viewpoint, the National Aeronautics and Space Administration has contributed significantly to the solution of noise suppression problems. Specificially, the engine noise suppressor which has been developed by the General Electric Co. for the CJ–805 engine was derived basically from a NASA design. In addition, NASA has provided much useful theoretical and analytical work on the basic nature of noise production, in addition to valuable experimental work. It is our opinion that NASA has devoted sufficient effort to keep abreast of the problems in this area.

11. Our legal problems resulting from noise in our development programs have been minimal. Experience has produced some modification in our programs and techniques in order to avoid repetition of earlier problems.

We would appreciate receiving copies of your composite statement as made to the House Committee on Science and Astronautics.

Sincerely,

J. V. NAISH, *President.*

THE MARTIN CO.,
Baltimore, Md., August 16, 1960.

Hon. OVERTON BROOKS,
Chairman, Committee on Science and Astronautics,
House of Representatives, Washington, D.C.

DEAR MR. CHAIRMAN: By letter of July 19, 1960, Mr. Charles F. Ducander, executive director and chief counsel of your committee, invited us to submit a statement for inclusion in the record of the proposed hearings to be conducted by the committee on the problems of jet aircraft and missile engine noise and its effects on men and machines. We understand the hearings, originally scheduled to begin on August 16, have been postponed until August 23.

The Martin Co. is well aware of these noise problems and their effect on men and machines and has conducted an acoustic program dealing with them since 1950 at a cost of approximately $2,500,000. We have acoustic facilities at both our Denver and Baltimore divisions sufficient to support the engineering development and the environmental testing required for our missile, electronics, and nuclear business.

Our engineering staff is active in the study of sonic fatigue of structure and the environmental testing of equipments. In certain specific instances consultants have been retained to advise and assist in problems such as the jet noise problem at the Martin-Baltimore Airport, noise suppression devices for jet engines, and for rocket engine captive firing during development testing.

The Martin Co. is interested in all facets of the noise problem and has experience in those areas concerned with operating aircraft. However, other companies still active in the production of aircraft are in a more up-to-date position to report on these problems. Therefore, we will confine our remarks to some acoustic problems peculiar to large boosters and missiles.

Boosters such as Saturn and Nova with their larger thrust engines amplify the noise problems of the present ICBM's. The static firing of such vehicles creates high-intensity, low-frequency noise. Recent studies at the Martin Co. indicate that a 12-million-pound thrust engine would create objectionable noise at distances up to 10 miles. The acquisition of large tracts of uninhabited lands for test sites becomes expensive since logistical and transportation considerations considerably narrow the choice. For these engines the size of noise suppression devices that follow conventional muffling concepts becomes prohibitive. Little is known about the suppression of noise in the subaudible and first audible octaves. Conse-

quently, a necessary step in the acoustics problem is further research and development in muffling techniques for the suppression of this low frequency noise.

We appreciate the opportunity to submit this statement and shall be glad to continue to cooperate with your committee.

Very truly yours,

W. B. BERGE.

GRUMMAN AIRCRAFT ENGINEERING CORP.,
Bethpage, Long Island, N.Y., August 17, 1960.

Mr. CHARLES F. DUCANDER,
Executive Director and Chief Counsel, Committee on Science and Astronautics, House of Representatives, Washington, D.C.

DEAR MR. DUCANDER: We are pleased to cooperate with the U.S. House of Representatives Committee on Science and Astronautics in response to your letter of July 19, 1960, which offers the opportunity to express our views on the problem of noise and its effects on men and machines.

The following views or opinions on the points you indicate of interest to the committee are based on our experience which includes the design, production, testing, or operation of—

Military turbojet and propeller-driven aircraft.
Our turboprop corporate airplane, the *Gulfstream*.
Engine and small rocket test stands.
Two airfields, one at Bethpage, Long Island, and one at Peconic River, Long Island.

1. The major portion of our investment on noise problems is in the area of engineering design to minimize the effects, establish procedures for operation of our airfields and our equipment in order to reduce the effects of noise on men, machines, and surrounding communities.

2. We have a small noise and accoustical laboratory with an average of four full-time people performing experimental engineering work. Approximately seventy-five thousand dollars' worth of equipment is available for measuring, recording, and analyzing noise and vibration signals and for generating test noise levels up to 165 decibels using a high intensity siren.

3. Although no consultants are retained in the field of noise and bioacoustics, contact is maintained with the various organizations working on these problems by direct contact or through their published information. In 1957 the Bolt Berenac & Newman Co. were requested by the Navy to do a study of anticipated noise due to aircraft operation at our Peconic River facility.

4. The noise made during takeoff and landings of our aircraft has not generated sufficient public reaction for us to be able to comment on the adequacy of the FAA acceptable noise parameters.

No complaints have been received resulting from operation of our corporate airplane, the *Gulfstream*, by us primarily from the Bethpage facility or by our customers throughout the country. This airplane is equipped with two Rolls Royce RDa7/2 turboprop engines and Rotol four-bladed propellers. It has satisfactorily passed the Port of New York Authority acoustical tests.

Operations at the Peconic River Airfield in addition to the military aircraft include training flights with Constellation-707, and DC–8-type aircraft. Considerable effort has been expended to establish traffic patterns and procedures to minimize the noise effects on the local communities. These requirements are generally higher than those required by FAA. This is primarily because of the maneuvers and power settings used in various of the training-type operations.

In general, establishment of reasonable operating procedures and maintaining contact with representatives of the local communities has resulted in alleviating the problem.

5. We have made only preliminary study of noise problems associated with supersonic transports. However, we have been working on design against structural sonic fatigue for several years on our current and future aircraft. Adequate design of structures that will withstand the sonic energy is complicated by the fact that sonic fatigue is generally a low-stress level phenomena requiring many cycles of vibration before damage occurs. Establishing adequate correlation between the type of noise and the wide variety of structures is a large task. The local stress concentrations resulting in

eventual failure are produced by many factors. Prediction of these concentrations in new designs is hampered by the relatively small amount of this correlating information currently available. Actual test of specific structure under actual noise conditions expected is presently the only sure method of obtaining a completely satisfactory design.

6. Although there are extensive efforts in organizations such as WADC, NASA, and in private industry, it does not appear to be a truly coordinated program. The more than probable loss in efficiency of design has resulted in little being accomplished in design of engines, aircraft, or missiles with emphasis on noise reduction. At the same time much of the information obtained on noise and vibration suppression seems to be treated as proprietary by many of the firms. It is felt that a more concentrated effort could be placed on reduction of noise levels during ground testing when efficiency is not of prime importance.

7. Technical aspects of the noise problem are not being overemphasized. Lack of complete knowledge of all parameters involved results in design to avoid problem areas, failure of structure or equipment in unsuspected areas, inefficient operation of men and machines. This results in costly redesign or repairs and physical effects on personnel that may not be repairable.

8. We have had no direct experience in the field of static testing or flight-testing of large rockets and missiles, and therefore do not feel qualified to comment.

9. Specific attention is given to interior and exterior noise and acoustics, aircraft carrier and land-based suitability, ground support equipment, engine, and small rocket test facilities. All available and authorative sources of information pertinent to the psychological and physiological problems of personnel working in noise environment around jet aircraft and rockets are drawn upon by full-time staff psychologists and physiologists. This provides broadest coverage, scrutiny of data, and opportunity for selection from all possible solution. Sources of information include organizations such as: USAF School of Aviation Medicine, Harvard Psycho-Acoustic Laboratory, WADD Aero Medical Laboratory, Office of Naval Research, Naval Medical Research Institute, and the Engineering Experiment Station of the University of Illinois.

10. It does not appear that problems we are facing in regard to noise suppression or its effect on specific structural designs will be covered by the NASA programs to the extent that we require. In regard to suppression of engine noise, most information has been generated by engine manufacturers. Such methods or devices affect performance and are therefore soon discarded.

11. To date, the legal problems resulting from noise generation associated with our development efforts have not been significant. We have not been involved in any litigation resulting from noise generation. While there have been a number of complaints from persons residing adjacent to our flight test facilities over the noise created by jet aircraft, we have been able to placate these persons, for the most part, by making adjustments in our operating procedures, flight patterns, hours of operation, etc., where possible, and we are not having a serious problem in this regard at the present time. There have also been one or two cases of damage attributable to sonic booms created by aircraft in our control. These claims have not been appreciable in amount and have in each case been settled promptly.

We hope that the above information will assist the committee in its efforts to establish an organized approach to solving the problems associated with designing noise out of these systems without loss of efficiency in design. Should any additional information be desired, we would be pleased to further assist in this effort.

Very truly yours,

WM. T. SCHWENDLER,
Chairman of the Executive Committee.

DEPARTMENT OF THE ARMY,
OFFICE OF THE SECRETARY OF THE ARMY,
Washington, D.C., August 19, 1960.

Hon. OVERTON BROOKS,
Chairman, Special Investigating Subcommittee,
Committee on Science and Astronautics,
House of Representatives.

DEAR MR. CHAIRMAN: During the first week in August Capt. Howard J. Silberstein, USN, indicated to Colonel Goodwin of this Office that the special investigating subcommittee would read into the record any statements that the Department of Army desired to make on noise suppression matters. Captain Silberstein also indicated that Army witnesses could be scheduled if desired by Department of Army.

It is requested that the enclosed Department of Army statement be placed in the record of your subcommittee hearings.

The Department of Army does not desire witnesses to present testimony before the subcommittee.

Sincerely,

R. L. VITTRUP,
Major General, GS,
Chief of Legislative Liaison.

INFORMATION OF INTEREST TO SPECIAL INVESTIGATING SUBCOMMITTEE OF THE HOUSE COMMITTEE ON SCIENCE AND ASTRONAUTICS HEARINGS ON NOISE SUPPRESSION WHICH THE DEPARTMENT OF ARMY DESIRES TO HAVE READ INTO THE RECORD

1. Although Army aircraft of today are relatively quieter in comparison with the jet aircraft of the other services and those coming into the civil fleet, the Army is intensely interested in reducing the noise level of our present aircraft and assuring that our aircraft of the future will have minimum noise levels. This is particularly important if we are to achieve the element of surprise required in the combat area and we are emphasizing this point. Some progress has been made by the Army in reducing the noise level of its aircraft by using turbine engines in lieu of reciprocating engines. For example, the HU–1A Iroquois helicopter and the AO–1 Mohawk airplane powered with the T–53 gas-turbine engine are significantly quieter than aircraft powered with comparable reciprocating engines. Actual noise measurements of the HU–1A helicopter, powered with the 825-horsepower turbine engine, and the model 47J Bell helicopter, powered with a 260-horsepower reciprocating engine, show overall sound pressures of 79 decibels and 78 decibels, respectively, when measured at 500 feet altitude.

2. The Army's problem in noise suppression is not solved by the simply substitution of turbine engines for reciprocating engines, however, since the engine is not the only source of noise and indeed in many cases not the significant source. Much of the noise in rotary wing aircraft is derived from the rotors and in the case of aircraft with small propellers, particularly those visualized in some future concepts of aircraft, the loudest noise will probably come from propellers or rotors.

3. In many cases minor design changes can affect materially the noise level without serious degradation in performance. The Army is constantly alert to this fact and will monitor all of our projects with the purpose of assuring minimum practicable noise levels.

4. Sometimes noise reduction can be achieved by muffling or by use of other devices, but only at the expense of reduced performance, increased weight, and increased costs. The impact of degradation in performance must always be weighed against the benefits obtained by decreased noise. This is true in civil aviation and probably even more true in military aviation where performance is vital.

5. The Army is devoting considerable effort to isolating the problem areas, that is, identifying the noise sources and the types of noises that are most objectionable, both from the viewpoint of physical effects to occupants of the aircraft and irritation to individuals in the proximity of the aircraft, as well as from the viewpoint of tactical operations where stealth is essential.

6. The noise level must be carefully watched since in general it can be stated that noise will increase with horsepower and performance, and the objectives throughout aviation, military and civil, is to achieve higher and higher performance of aircraft.

7. Detailed answers to certain questions within the Army sphere of interest posed by the subcommittee are attached.

ANSWERS TO QUESTIONS OF INTEREST TO THE SPECIAL INVESTIGATING SUBCOMMITTEE OF THE HOUSE COMMITTEE ON SCIENCE AND ASTRONAUTICS

Q. 1. What are the major noise problems confronting the Army in operating Army aircraft?

A. 1. The noise levels experienced in current Army aircraft are such that the occupants experience, in varying degrees, excessive fatigue, temporary (and in some cases permanent) hearing loss, loss of coordintion, and almost complete dependence on intercommunications systems. In addition, with the extended range of future helicopters, it is not believed the crew can sustain flights of such duration without suffering to some degree hearing loss or excessive fatigue.

If a V/STOL (vertical start takeoff and land) operational evaluation aircraft is finally decided upon, there will be tremendous problems associated with the two types presently proposed.

For the compound aircraft, the tip burning pressure jet rotor system is favored. The noise produced by the pressure jets themselves is the main offender with the vortex noise produced by the blades a secondary offender. The noise near the source for this type of machine can reach 130 db or more.

For the tilt wing type aircraft, the propellers will have to be relatively small in size and therefore of high disk loading. This machine will produce a very high noise level due to the highly loaded propellers turning at a high r.p.m.

If an aircraft using a hot cycle pressure jet rotor for lift is developed, some means to attenuate the noise produced by this type of propulsion system is needed.

Helicopters using jet flap rotor systems for lift and control show great promise. If this type of machine is used, there will probably be noise problems. Some effort should be devoted toward a study of attenuating the noise produced by this type rotor system.

Q. 2. What effort in research and development test and evaluation has the Army made to combat the psychological and physiological problems confronting personnel in high noise environment?

A. 2. Transportation Research and Engineering Command, Fort Eustis, Va. (Trecom) is currently conducting an acoustical research program as applied to Army aircraft in which psychological and physiological considerations are made. A brief outline of the current program is as follows:

Task I: Detailed internal and external noise measurements of current Army aircraft have been made. An advance copy of the data obtained in this part of the program is attached (enclosure 1).

Task II: An investigation is being conducted to determine the noise intensity to which crew and passengers may be exposed without causing fatigue, temporary loss of hearing, loss of efficiency, coordination, etc. (A description of the technique employed will be presented in answer to question 4). Based on the results therefrom, a cursory design study will be conducted to estimate the loss of performance experienced with the application of sufficient acoustical treatment to reduce noise levels to acceptable limits.

Task III: A review of the current specification on noise levels in aircraft (MIL–8806) will be conducted to determine its adequacy to meet Army requirements in light of the work conducted above.

Q. 3. What is the approximate dollar value of the research, development, test, and evaluation (R.D.T. & E.) effort to combat the noise problem? (to be broken down by years).

A. 3. A list of the funding (in thousands of dollars) both previously committed and that programed for future years is as follows: Fiscal year 1959, 42; fiscal year 1960, 4; fiscal year 1961, 250; fiscal year 1962, 250; fiscal year 1963, 150; fiscal year 1964, 100.

Q. 4. What has been the contribution of the Army to the major scientific effort in noise study and suppression?

A. 4. At the time of the initiation of the current program, it was anticipated that a survey of available information in the literature and interviews and consultations with experts in the field would provide the necessary information upon which to base noise level requirements acceptable for Army aircraft. It became clear in the early stages of this survey, however, that such information was not available in sufficient detail, and, in fact, acknowledged experts in the field of acoustics stated specifically that the noise level measurements taken on Army aircraft under task I (see above 2) would, if correlated with a pilot opinion

survey, provide basic data for the establishment of the desired criterion of a more reliable nature than anything else known to exist at this time.

Accordingly, an opinion survey of Army pilots was initiated in November 1959, with the intent of deriving the desired criteria from a statistical correlation of pilot opinion with acoustic data taken in task I. Specifically, the establishment of the criterion has been based almost entirely on the basic data obtained during this program, and the survey of existing information obtained by literature search and consultations will be used essentially to corroborate the proposed criterion within the limits of established psychological and aeromedical criteria.

Q. 5. How does the Army cooperate with other services, National Aeronautics and Space Administration (NASA), and industry in the areas of noise study?

A. 5. Prior to the initiation of the existing program, several visits were made to Wright Aeronautical Development Division, Wright Field, Dayton, Ohio (WADD), to review the work previously done by the Air Force and in those areas of acoustics application to Army aviation. Upon preparation of the detail program, the Air Force rendered assistance and made comments pertinent to the problem. Liaison has been maintained with Air Force during the course of the program. At the conclusion of this program, the revisions of military specification No. 8806 must receive Air Force concurrence. In addition, the Trecom project engineer will continue to review all available technical reports from both industry, Air Force, and Navy.

In the formulation of the work planned for fiscal year 1971, which is to develop means by which source attenuation can be accomplished, a visit was made to the U.S. Navy Engineering and Experimental Station, Annapolis, Md., in order to review the work done by that agency, in the reduction of gear-generated noise, and a visit is planned for August 18, 1960, to discuss the current program with Maj. James Albright at Walter Reed Hospital. A visit is also planned for August 25, 1960, to NASA laboratories at Cleveland, Ohio, to obtain NASA comments on the current work. Discussions have been held also with the cognizant personnel at NASA, Langley Field, Va.

Q. 6. Do you feel that NASA is devoting sufficient effort in the area noise study which would lead to the solution of the Army problem?

A. 6. No. The NASA is devoting very little effort if any to the Army noise problem.

Q. 7. What does the Army feel should be done in solving the Army aircraft noise problem which is not yet done?

A. 7. Recommendations have been made by Trecom for a noise program from fiscal year 1961 through fiscal year 1964 which will be conducted in two areas: Internal noise levels and external noise levels.

The internal noise program will be directed toward source attenuation of acoustically offensive dynamic components. Current attentuation technique requires the application of large amounts of absorbent blankets, damping tape, etc., which result in an excessive weight penalty. It is believed that reduction of noise at the source can be accomplished with little, if any, weight increase.

The external noise program should be directed as follows:

Tip burning pressure jet rotors
Hot cycle pressure jet rotors
Pressure jet type rotor systems
Highly loaded small diameter propellers
Turbine intake and exhaust
Studies showing what trade-off in payload and performance would be necessary to reduce the noise problem associated with aircraft using the above type propulsion and lift systems

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NORTH AMERICAN AVIATION, INC.,
Los Angeles, Calif., August 25, 1960.

Mr. CHARLES F. DUCANDER,
Executive Director and Chief Counsel, Committee on Science and Astronautics, House of Representatives, Washington, D.C.

DEAR MR. DUCANDER: Receipt is acknowledged of your recent letter relating to the hearings to be held by the U.S. House of Representatives Committee on Science and Astronautics on the problems of noise and its effects on men and machines. The study of these problems by the committee is timely and I am sure that as a result of the hearings and other material developed a constructive program will be proposed.

Our answers to the specific questions which you have raised in your letter are set forth below in the order in which your questions appeared.

1. It is difficult to attach a specific dollar value to complete effort of noise suppression and accompanying research and development programs in effect for more than 10 years at North American Aviation. The current estimate is in excess of $2 million.

2. North American has extensive facilities for the measurement and analysis of noise in flight and on the ground. Recording is done chiefly on tape and both manual and automatic analyzers are used for data reduction and analysis. An anachoic chamber is available for microphone calibrations, reverberant chamber for acoustically testing equipment items to be used in the air vehicles, and a high intensity siren facility is available for a variety of acoustical test work, its chief use being for sonic fatigue tests of structural components.

3. We have from time to time retained the services of both the Bolt Beranek & Newman Co. and Paul Veneklasen & Associates, who are nationally recognized authorities in the field of acoustics.

4. We do not feel qualified to comment on this question at this time.

5. The problem of the sonic boom will require the control of climb, descent, flight paths, and altitudes to a greater extent than is done at present. It appears that sonic structural fatigue is a problem that can be adequately handled by existing analytical and test procedures. The takeoff and approach noise reduction problem has many aspects which require extensive research and development to achieve the optimum powerplant modification and flight path angles.

6. Yes; there is a coordinated program between the military and its contractors to solve the noise problems pertinent to structural fatigue, crew comfort, and maintenance personnel as well as in-flight operations and the communities adjacent to airports and under the flight path. Specific designs are governed by special design noise level goals. Coordinated effort in terms of research contracts investigating various phases of the noise problem are underway.

7. No. The noise problem has not received sufficient emphasis in the overall view though in certain areas there has been a considerable emphasis recently.

8. Our experience in this field has led us to believe that all static testing of large rocket engines and missiles should be conducted in fairly remote areas as witness our facility at Santa Susana, Calif., and our plans for additional facilities in areas north of Reno, Nev.

9. We have made physiological and psychological studies of the effect of noise on personnel—chiefly through outside consultants, but have been guided in the main in our design of aircraft and in personnel working conditions by the published permissible environmental noise levels specified by the Air Force.

10. The NASA has conducted valuable experiments in the field of acoustics and no doubt will continue in this area. While test programs are proceeding adequately in many fields there is need for additional research in the measurement of aerodynamic noise in flight and for fundamental research on propulsion systems.

11. We have not as yet been confronted with legal problems resulting from noise generation associated with our development efforts.

We trust that this will prove to be helpful to your committee and if we can cooperate in any other way, we shall be pleased to do so.

Sincerely,

J. L. ATWOOD, *President.*

AIR TRANSPORT ASSOCIATION,
Washington, D.C., August 30, 1960.

Mr. CHARLES F. DUCANDER,
Executive Director and Chief Counsel, Committee on Science and Astronautics, House of Representatives, Washington, D.C.

DEAR MR. DUCANDER: We appreciate the invitation to submit data to the Committee on Science and Astronautics in connection with its hearings on noise.

The Air Transport Association, in conjunction with other aviation interests, participates in the National Aircraft Noise Abatement Council. That agency is coordinating the varied efforts of the air transport industry in connection with this subject. Your questions were referred to that organization, and the answers

are contained in the attached memorandum from Jack R. Cram, president of the National Aircraft Noise Abatement Council.

Cordially,

S. G. TIPTON.

NATIONAL AIRCRAFT NOISE ABATEMENT COUNCIL,
Washington, D.C., August 29, 1960.

MEMORANDUM

From: Jack R. Cram, president, NANAC.
To: Stuart G. Tipton, president, ATA.

The following comments are furnished in reply to your request for information available to NANAC on programs being conducted by the air transport industry in the area of aircraft engine noise suppression. We understand the congressional hearings for which this material is required will primarily deal with the problems associated with designing noise out of engines and in the research and development activities associated with the psychological, physiological, and engineering problems involved in jet-aircraft operations. However, inasmuch as the principal noise problems created by air transport operations are mainly due to the noise annoyance caused the residents living in our airport neighborhoods, we have oriented our answers to the questions proposed by the House Committee on Science and Astronautics toward this aspect of the problem.

We believe the noise annoyance now being created by some jet-aircraft operations stems in a large measure from the fact that the present generation of commercial jet aircraft are using engines basically designed for military purposes. These engines, which were the only ones available at the time of the design of our present generation of civil jet transports, were developed with no design requirement for minimizing their noise output. The civil air carriers, however, recognizing from the beginning that jet-engine noise would be a serious problem, set, as a basic requirement for all civil jet transports, the incorporation of the best possible sound suppressors the state of the art made it possible to produce. To fulfill this requirement, the manufacturers have invested heavily in research to develop noise-suppression devices.

One airframe manufacturer estimates its research and development costs for the suppressors used on its jet transports to total in excess of $6 million. Another estimates its research and developmental costs on sound suppressors to be in excess of $15,500,000. Two other airframe manufacturers, even though they have had the full benefit of all previous research by other manufacturers, report they have expended more than $2,500,000 each on noise-suppression research. Engine manufacturers have invested additional multiple millions of dollars. These developmental costs have of necessity been passed on, in part, to the carriers, thus substantially raising the delivery price of each aircraft.

The suppressors now installed on all civil jet aircraft produce a considerable sound reduction. This reduction is not, however, achieved without the payment of substantial and continuing penalties.

The use of noise suppressors results in an average 4-percent increase in flying time and fuel consumption on short-range flights. They account for an average 2-percent increase of flying time, and a 9-percent increase in fuel consumption on long-range flights.

As of August 1, 1960, there were 13 U.S. air carriers operating a total of 169 turbojet-powered transports. A cost accounting breakdown of the additional monthly operating costs due to the use of suppressors made by one carrier now operating a fleet of 24 jet aircraft, is as follows:

	Per month
Increased operating cost (level flight)	$181,690.83
Increased operating cost (climb)	29,458.98
Payload loss due to suppressor weight	23,592.16
Payload loss due to fuel weight	4,191.52
Repairs	2,000.00
Total	240,932.49

Applying this figure to the total turbojet fleet now in operation, we can conclude the carriers now operating turbojet aircraft are paying approximately $1,700,000 per month for noise suppressors.

In addition, the major airports now handling long-range jet flights are expending millions of dollars to lengthen their principal runways. While some additional

runway is required by jets for takeoffs due to the reduced performance caused by the use of suppressors, these extensions, which in some cases amount to as much as 3,500 feet, are principally being made for noise abatement purposes. The average cost of constructing runways today is estimated to be $1,000 per foot.

Because of requirements stipulated by the air carriers, the engine manufacturers are vigorously pursuing intensive research programs to develop jet engines which are basically quieter. These programs are beginning to produce encouraging results, and there is reason to believe that additional noise reductions within the engine itself can be achieved within the foreseeable future.

Turbofan engines, which are quieter per pound of thrust than the present turbine engines, are now being installed on many civil jet aircraft being delivered. Many carriers are also planning extensive retrofit programs to install these engines on the aircraft they now have in operation. This shoud help alleviate some of the noise annoyance, providing the additional thrust is used to increase takeoff performance.

It must also be pointed out that even a major breakthrough would not solve our existing noise problems. The present generation of engines now being used will be with us for some years. In view of these facts, we believe the air transport industry is fully aware of its responsibilities and is taking every reasonable measure to alleviate to the maximum possible degree the noise annoyance caused by its operations.

We feel that it is equally important that local civic governments become aware of their responsibility to help alleviate noise annoyance problems by taking a realistic view towards rezoning noise critical areas in airport neighborhoods. We also feel it is important to note that the United States is the only country in the world today whose air transport system is totally privately owned and operated and that the net profit made by all U.S. air carriers last year amounted to only 2.7 percent of total revenue. The railroads in the same period showed a profit margin nearly three times as great.

Every reasonable measure suggested by NANAC to alleviate the present noise problem is being taken, and every avenue of research is being pursued to bring about its ultimate solution. If our air transportation system is to operate without Government subsidy, our airlines must not be subjected to restrictive local or Federal regulations which limit gross takeoff weights, limit runway use or times of operation.

The further economic penalties imposed by such regulations would wipe out the present small margin of profit and place our air transport system in an economically untenable position. Our replies to the committee's specific questions are as follows:

Question No. 1: An estimate of the dollar effort that the air transport industry has invested in research, development, test, and evaluation in the area of noise suppression in transport aircraft.

We do not believe it possible to fairly indicate in terms of dollars alone the intense effort that has been directed by the manufacturer and the air carriers toward the solution of the aircraft noise problem. An estimate generally accepted within the industry, however, places the total amount expended by the entire industry for research, development, test, and evaluation to date at approximately $50 million.

Question No. 2: Does your organization retain consultants in the field of noise and bioacoustics, such as Bolt, Berenak, and Newman Co.?

The air carriers have not retained special acoustical engineering consultants except in one or two isolated cases for the purpose of securing data relating to problems of aircraft internal noise. Several carriers, however, do employ as permanent members of their staffs, engineers knowledgeable in the field of acoustics. The manufacturers of both airframes and engines, because of the requirements for noise suppression specified by the carriers, have assembled staffs of experts in the acoustical field. The knowledge they develop is made available to the carriers. We feel that it should be noted that the efforts of consultants, such as the firm named by the committee have been primarily directed toward evaluating the effectiveness of current finished products. They have, to our knowledge, made no contribution to either research or development.

Question No. 3: Can you comment on the adequacy of the acceptable noise parameters as set forth by the FAA?

We know of no "acceptable noise parameters" developed and set forth by the FAA. Some private organizations have made attempts to set rigid acceptable noise levels on a local basis. We feel so many variables and so many natural factors, such as humidity, temperature, wind, weather, terrain, and a host of

other items, including the difference in noise levels to which individuals react, that the establishment of rigid maximum permissable noise levels do not appear to be practicable at this time. However, we feel that an unbiased study by an independent group, such as the National Bureau of Standards, should be made to attempt to establish a criteria for the measurement of aircraft noise.

Question No. 4: Can you discuss the noise problems associated with the design of a supersonic transport covering such things as sonic booms, sonic structural fatigue, and problems associated with takeoff and approach noise reduction?

We do not feel we can discuss at this time any of the problems associated with supersonic flight. Information on this subject should be available through the manufacturers, the NASA, and the military. We understand that the manufacturers are submitting information, including their opinions, on this subject directly to the congressional committee.

Question No. 5: Do you feel that there is a coordinated program, both in Government and in private industry which is oriented to solve the noise problem?

We believe the industry and the governmental agencies with a responsibility in this area fully recognize the urgent necessity for solving the aircraft noise problem. The organization of NANAC by the Air Transport Association, the Aerospace Industries Association, and the Air Line Pilots Association, and the unreserved support we have received from our founding organizations and their members, is clear evidence of the cooperation and determination of industry to take every safe and reasonable measure to solve the noise problem The FAA and NANAC have fully coordinated their programs for the development of standard industrywide operating procedures to reduce aircraft noise to the lowest possible levels consistent with safety. The FAA has reviewed NANAC's noise abatement manual and has offered many helpful suggestions. This manual incorporates noise abatement procedures developed by the FAA.

There has been excellent local industry-Government cooperation in noise abatement programs for a number of years. The cooperation the FAA has extended to NANAC toward the development of a coordinated national noise abatement program has been outstanding.

Question No. 6: Do you feel that the problem is receiving overemphasis?

The question of whether the problem is receiving overemphasis cannot be answered by a single statement. The carriers and the engine manufacturers are now giving the problem tremendous emphasis. Generally speaking, however, we feel that longer range planning and research could be intensified so that when new equipment such as supersonic and STOL and VTOL aircraft come into use the Government and the industry will be ready to deal with the problems they pose. We, therefore, believe that the aviation industry is properly placing great emphasis on this problem, and that the degree of emphasis is in keeping with the seriousness of the problem.

Question No. 7: Does your organization study the psychological and physiological problems of personnel who work in a noise environment around jet aircraft?

The airlines have made extensive use of the material developed by the manufacturers and the military on the psychological and physiological problems of personnel who work in a noise environment around jet aircraft and have adapted this knowledge for their own use. Several carriers have also conducted private studies into these areas. Personnel who work in a jet engine noise environment must use presently known protective devices and receive periodic physical checks. The carriers are also maintaining a close liaison with the military and industrial groups who have been concerned with this problem, to keep fully abreast of all developments in this field.

Question No. 8: Do you feel that the National Aeronautics and Space Administration is devoting sufficient effort in the area of noise studies which would lead to the solution of your problems?

In the past NACA made significant contributions to the basic understanding of noise. Its research and development efforts provided much of the information upon which the noise suppressors currently in use were designed. However, the reorientation of NASA toward space systems has resulted in virtual elimination of research efforts applicable to aircraft noise problems. We believe Congress should provide sufficient funds for this research and NASA should reactivate and conduct an intensive research program in the area of aircraft noise suppression, including SST aircraft.

Question No. 9: Have you been confronted with legal problems resulting from noise generation associated with your development efforts?

We have no knowledge of any legal problems resulting from developmental efforts on the part of the airlines. There have been, as you know, many legal problems and lawsuits resulting from noise annoyance caused by aircraft operations. These auits have resulted in decisions by the courts which emphatically recognize the authority of the Federal Government to "regulate the operation of aircraft and control the use of the airways." Local ordinances, which set forth laws contrary to Federal regulations, have been held to be unlawful.

JACK R. CRAM, *President.*

UNITED ACOUSTIC CONSULTANTS,
Darien, Conn., August 30, 1960.

Subject: Aircraft noise hearing

Hon. OVERTON BROOKS,
Chairman, Committee on Science and Astronautics,
Washington, D.C.

DEAR CONGRESSMAN BROOKS: It was very kind of you to take time from your busy schedule during the hearings of the committee to see me.

You are to be commended for the excellent coverage of important groups working in the aircraft noise field. As you indicated, it is difficult to hear all of those who have contributed to the understanding of the aircraft noise problem, and it is understandable why, at this time, your committee could not hear us. Since other consultants have been heard, the committee might be interested in hearing about our research and ideas in this area of acoustics.

As early as 1942, we became involved in the measurement of the aircraft engine and propeller noise. With the advent of jet aircraft following World War II, I was assigned to the noise control committee of the Aircraft Industries Association. One of the important results of this committee was the development of a series of standards establishing instrumentation specifications, calibration procedures, and measurement methods. To my knowledge this was the first to be developed, and it relieved confusion existing at that time in the noise abatement of aircraft test facilities. As is the case now, the lack of standards at that time was mainly responsible for inaction due to economic uncertainties. As brought out in last week's hearings, the need for new standards has been clearly demonstrated for both airport communities in the jet airline age and for sonic booms.

To assist in the development of these acoustic standards, a strong need has been expressed for a sizable independent group of acoustic consultants to which Government and industry may turn to gain support of the national scientific community. This group is known as Associated Acoustic Consultants and has its headquarters in Darien, Conn. As managing director of this group, I would like briefly to summarize some of the talents of the other scientists in the association.

The roster includes men who have made fundamental investigations of the character and cause of all forms of aircraft propulsion noise. They have published numerous papers in various scientific journals and met with most of the national committees concerned with the subject of aircraft noise over the past 15 years. For a number of years another of the scientists directed one of the largest acoustical research groups in the country and has been responsible for a long list of scientific achievements published in appropriate scientific journals. He is a fellow of both the Acoustical Society of America and Institute of Radio Engineers. Perhaps his most outstanding achievement was the development of a noise zoning law for the city of Chicago. A third group has worked in the field of physiological acoustics and has published one of the basic acoustic texts now used widely at institutions of higher education throughout the country. These are but a few of the associates and their capabilities are detailed merely to indicate the breadth of their experience in the field applicable to the present aircraft noise problem.

The associated acoustic consultants look forward to contributing substantially in the research effort needed to permit an orderly development of air transport compatible with the communities it serves. This independent firm will be delighted to assist the committee in any way possible.

Again, thank you for your courtesy and extend our congratulations to the committee for their timely hearings.

Very truly yours,

STANNARD M. POTTER, *Managing Director.*

AIRPORT OPERATORS COUNCIL, INC.,
Washington, D.C., August 31, 1960.

Hon. OVERTON BROOKS,
Chairman, Committee on Science and Astronautics,
House of Representatives, Washington, D.C.

DEAR CONGRESSMAN BROOKS: We appreciate very much the opportunity you have afforded us for placing a statement of our views in the record of hearings on aircraft noise, August 23–25, 1960.

Should you desire further information regarding this matter we shall be happy to provide it.

Sincerely,

E. THOS. BURNARD,
Executive Vice President.

STATEMENT OF E. THOMAS BURNARD, EXECUTIVE VICE PRESIDENT, AIRPORT OPERATORS COUNCIL, WITH RESPECT TO AIRCRAFT NOISE

Although the current hearings have been described by Chairman Overton Brooks as directed to the scientific aspects of aircraft noise reduction and suppression, the entire subject of annoyance from aircraft noise has many other aspects which are of importance as guides to those approaching the subject from a scientific viewpoint. Testimony on some of these aspects was heard from Government agency witnesses. Because of the effect of aircraft noise on communities which are served by civil jet aircraft and because of some statements both in testimony and in the preliminary staff report on "The Effect of Noise on Man and Machine" (released by this committee on August 21, 1960), the Airport Operators Council welcomes the opportunity to make this statement to assist the committee in its deliberations on this complex subject.

In the preliminary staff report we believe there have been important omissions under section VI, entitled "How To Attack the Noise Problem"; and some of the suggestions which were included have, in our opinion, such severe limitations as to make them of doubtful value. On these points we think we can be of some assistance to the committee.

First, we should like to indicate the role of the airport operator in the aircraft noise picture.

ROLE OF THE AIRPORT OPERATOR

Large commercial airports in the United States are almost all owned and operated by a municipal, county, State or Federal Government, an agency thereof, or some special agency created by a legislature to combine the interests of one or more of these units of government. Thus, the so-called airport operator is usually a governmental body which owns or operates the airport. Those having direct responsibility for the development, management, and operation of most airports are rendering a public service in a field which is also an integral part of a national and international air transport business.

With respect to aircraft noise the airport operator finds himself in the role of being greatly interested in the welfare of both the aircraft operators on the one side, and the residents and property owners in the community on the other; and he seeks to find a proper balance of interests between the two.

This committee has received the bulk of its testimony from the technicians immersed in specific aspects of aircraft noise at its source, and we trust that our views will provide useful background material for your consideration.

HOW TO ATTACK THE NOISE PROBLEM

We believe that the preliminary staff report has stated some conclusions in section VI, page 3 [1] which fail to mention two important means of reducing or eliminating noise annoyance from aircraft operations. These are—

(1) Improved operating procedures for existing aircraft; and

(2) Development of aircraft capable of higher angles of descent into and ascent out of airports.

[1] The preliminary staff report states that: "If noise cannot be totally reduced at the source, then other steps must be taken to accommodate the problem. These steps are—

"1. Better airport planning.
"2. Better air traffic systems.
"3. More consistent zoning laws for the area surrounding airports, missile and rocket sites.
"4. A recognition of the fact that building codes may have to change to require better insulation against noise.
"5. Public education on the problem."

IMPROVING OPERATING PROCEDURES FOR EXISTING AIRCRAFT

In addition to seeking noise reduction and suppression at its source, we believe that the next most productive step is to increase as much as is technically possible the distance between the operating aircraft producing the noise and the potential hearer. This can usually be achieved by altitude (vertical distance) and flight pattern (lateral distance). There are at least three direct ways to achieve this:

First, by direction of runway and by piloting technique. When wind conditions will permit, the pilot may be able to use a preferential runway aimed away from a community and thereby put a greater lateral distance between the aircraft and the citizens. Also, the pilot, by utilizing the available power for climb out, rather than increasing speed, can frequently separate the distance between the aircraft and the citizens more rapidly (by increasing vertical distance faster). A variation of this technique is to achieve a minimum altitude quickly, reduce power while flying over sensitive areas, and resuming climb power after the populated area has been passed.

On approach, the aircraft should be kept as high as possible as long as possible before landing.

These techniques are particularly important at night when the ambient-noise level of the community is low and aircraft noise sounds louder.

Secondly, in especially sensitive areas, by altering the gross weight of the aircraft. For instance, it has been found that takeoffs from a particular runway at a coastal airport can be achieved without community irritation only when (1) the wind conditions provide additional lift to the aircraft to get it higher above the community, or (2) the aircraft is taken off with lower gross weights. This may be the only way to solve the noise problem with present aircraft under certain operating conditions.

Third, the elimination of training flights from metropolitan areas. Experience with jet aircraft to date has shown that training flights conducted at metropolitan airports have created a community irritation problem or have aggravated one which was incipient or already existing. Removal of all such flights to remote airports, except for the minimum essential airport familiarization flights, will do much to solve the problem with present aircraft.

DEVELOPMENT OF AIRCRAFT CAPABLE OF HIGHER ANGLES OF DESCENT INTO AND ASCENT OUT OF AIRPORTS

A jet fighter with afterburner, under certain circumstances, may not create as much of a community annoyance problem as that of a civil jet transport because of the greater distance between the source of the noise and the hearer. The jet fighter may achieve this greater distance faster, both laterally and vertically because of a fundamental technical principle. That is, its thrust-to-weight ratio is very high. This is a high-performance aircraft, as well as a high-cost operation. This means that it has a tremendous amount of power in its engines to pull a relatively light airplane. A World War II PBY flying boat, by contrast, which was a low-performance aircraft, carried a lot of weight, had small engines and big fuel supply, and, when fully loaded, had to use miles of water for takeoff and then staggered along for many more miles trying to gain altitude.

Commerical transport aircraft are generally a compromise between these extremes. They are required to have enough power to meet certain minimum FAA safety regulations for climb capability and yet not so overpowered as to add cost which cannot be recouped in payload. Every technological advance to date in the aerodynamics of the aircraft as well as the improvement in efficiency of the powerplants has been used by the aircraft operators to increase payload potential. Each of these increases has resulted, however, in greater size and gross weight of the aircraft and little improvement in thrust-to-weight ratio, which has in turn required longer and longer runways, and has now resulted in community noise-annoyance problems because of the low-performance capabilities of the aircraft from a noise standpoint.

Building additional lift capability into civil transport aircraft through more efficient powerplants, boundary-layer control, jet flaps, and other high-lift devices would not only go far to reduce the noise annoyance problem, but would also make for greater efficiency, reliability, and economy of air transport operations. More specifically—

(1) Utilization and efficiency of air traffic control facilities, navigational aids and landing aids would be increased by processing more aircraft through less airspace in shorter time.

(2) Reliability of airline schedules would be improved by eliminating or reducing operational restrictions resulting from runway lengths, natural

obstacles in the takeoff and approach areas to airports; reducing air traffic delays; and speeding up ground operations by getting two shorter runways for the price of one long one.

(3) Greater productivity from airport investment would be achieved by halting the costs of ever-extended runways and getting more utilization out of present facilities.

One breakthrough in this direction appears to be in the use of the turbofan engine. Its makers claim it is inherently more powerful and quieter than its predecessors of comparable weight and size and if applied to present-day aircraft without increasing gross takeoff weight it can reduce both runway lengths and community noise annoyance problems by significant amounts.

Pratt & Whitney Witness B. A. Schmickrath testified before this committee that "We are convinced that the development and use of bypass or ducted fan engines will go a long way toward alleviating the takeoff noise problem * * *. Internal design of the engine and design of the air inlet and fan discharge ducts can have greater influence upon this [whine of the engine compressor] and we believe will provide future aircraft that will be decidedly less annoying on approach than those currently in operation."

FAA Administrator Quesada stated in this regard that "I'm hopeful that the airlines and the aircraft manufacturers will turn this added power [from turbofan engines] into added noise abatement to get the airplane out of the airport faster * * * which will bring substantial relief to the noise problem."

Another breakthrough came last weekend when it was announced that an Air Force contract had been let to flight test a revolutionary technique known as low-drag boundary-layer control. The aerodynamic principles of boundary-layer control, both high lift ("blowing") and low drag ("sucking") were proved out by the National Advisory Committee for Aeronautics, predecessor of the National Aeronautics and Space Administration, many years ago. The high-lift technique has been developed and used to some extent in military aircraft and can be made applicable to commercial transports. The perfection of the low-drag technique just announced holds high promise for the future. Either or both boundary layer control techniques are capable of producing these advantages:

(1) Increase takeoff ascent angle and thereby reduce noise annoyance (by lower gross weights resulting from less fuel to fly present route segments).

(2) Increase landing descent angle and thereby reduce noise annoyance on approaches (by reduced stall speeds and controlled "sink rate").

(3) Decrease runway requirements (because lower gross weights resulting from less fuel required for present route segments permits shorter takeoff run).

(4) Increase range. A plane with a normal range of 4,000 miles could go 7,000 miles with boundary-layer control (according to manufacturer's estimates).

It is the view of the Airport Operators Council that the time has come when these additional benefits from technological improvements must be shared with the taxpayers and the communities—and not go exclusively into higher payloads and greater revenues to aircraft operators as they have done in the past.

The special aviation advisers to the President, the Administrator of the Federal Aviation Agency, and the Senate Interstate and Foreign Commerce Committee, all have had occasion to state this essential principle in the past, but little has been done about it.

For that reason, the Airport Operators Council sincerely requests that this committee and other Members of the Congress take cognizance of these matters and assist the Federal Aviation Agency in the formulation of policy which will assure a greater recognition on the part the airline and manufacturing industry can play in the alleviation of noise annoyance and in the greater utilization of public airport and airway facilities.

A more complete and detailed statement of our views on these matters is included in a publication of the Airport Operators Council entitled "An Analysis of Aircraft Noise Annoyance and Some Suggested Solutions," March 1960. This document was written primarily for airport operators' use, but may be useful to the committee in this matter.

OTHER METHODS OF ATTACKING THE NOISE PROBLEM

The preliminary staff report of this committee has stated that[2] "if noise cannot be totally reduced at the source, then other steps must be taken to accommodate the problem. These steps are—

"1. Better airport planning.

"2. Better air traffic systems.

"3. More consistent zoning laws for the area surrounding airports, missile and rocket sites.

"4. A recognition of the fact that building codes may have to change to require better insulation against noise.

"5. Public education on the problem."

Except for item 2, we believe there are particularly severe limitations on the accomplishment of these objectives at existing airports and, further, we believe they should be considered only after every possible step is taken to solve the problem through the means outlined in the preceding discussion.

Item 1. "Better airport planning"

For instance, aircraft noise problems in the United States are found near some of the largest metropolitan areas where the airport has been in existence many years and the master plan for the airport has long since been approved by the Federal Government. Further, airport planning for this purpose cannot be improved until more authoritative guidance than now exists is received from the Federal Aviation Agency or from the air carriers. There are no rules or regulations of the FAA currently in effect which establish either—

(1) Noise level criteria for present or future aircraft, or

(2) Runway length requirements for future aircraft.

*Item 3. "More consistent zoning laws for the area surrounding airports, * * *"*

Dulles International Airport, now being constructed to serve Washington, is to be Federal owned and operated, but it is situated in two Virginia counties. Fortunately, the Government was able to acquire enough land in the initial purchase to obtain considerable buffer[3] between the ends of the runways and the edge of the airport boundary. However, the Federal Government is legally powerless to promulgate zoning laws in Loudon and Fairfax Counties outside the airport boundaries.

FAA Administrator Quesada told this committee that "persuasion" is the only available method. FAA General Counsel Daggett H. Howard supplemented this testimony by stating that a Federal Zoning Act has been considered but that it is the consensus of legal opinion that such an act would be of doubtful constitutionality. "Model zoning acts" he said, have "some promise" but where zoning laws have such vast economic consequences the likelihood of uniformity is "remote" and similar attempts have been "unproductive" in the past.

This illustrates a practical national problem. Frequently the legal body owning and operating the airport is in a jurisdiction different from that with the zoning power, and there may be little incentive on the part of the latter to deprive its citizens of any property interests. Further, the airport-administering body may have zoning authority prohibiting obstructions and hazards to aircraft or airport, but generally does not have land-use zoning authority. And many land-use zoning authorities do not have exclusive zoning powers which would prohibit residential developments in industrial-zoned areas.

Item 4. "A recognition of the fact that building codes may have to change to require better insulation against noise"

This suggestion has many of the same characteristics of zoning and has as many, if not more, limitations. Building codes are for the purpose of assuring safe buildings—properly engineered, properly constructed, using proper materials to assure the safety of the occupants against collapse, fire from poor electrical connections in hidden places, and the like. They do not envision protection against fumes, noise, smoke, or other annoyance created by industry. It is

[2] Sec. VI, p. 3.

[3] FAA Administrator Quesada testified that the area of land at each end of each runway is about the size of all of Washington National Airport.

industry that must muzzle the smoke stacks, muffle the noise and, in general, be good neighbors.

Item 5. "Public education on the problem"

We do not believe that it is a "solution" to try to convince taxpaying citizens that they should put up with aircraft noise. In fact, we do not believe this could be done.

First, every feasible means should be taken to assure the lowest possible noise of aircraft at its source. Then the airlines, the pilots, the airport operators and the Federal Government should do their part to hold down the noise of aircraft both departing and arriving. After that, the public should be informed of all of these joint efforts.

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